COKING COAL SUPPLIES TO STEEL PLANTS

AN ECONOMIC ANALYSIS OF

INDIGENOUS SUPPLIES VIS-A-VIS IMPORTED COAL

Final Report
April 1990

Sponsored by

Coal India Limited, Calcutta

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LIST OF FEASIBILITY REPORTS/DOCUMENTS REFERRED

1. Revised Project Report for Putki-Baliari mine (December, 1988) - CMPDI.

2. Feasibility Report (updated Cost Estimates) of Putki Washery (February, 1987) CMPDI.

3. Revised Project Report of Block II O.C. Mine (July, 1988) CMPDI.

4. Feasibility Report for Madhuband Washery - updated cost estimates (February, 1984) CMPDI.

5. Revised Cost Estimates for Rajrappa O.C. Mine (October, 1988), CMPDI.

6. Revised Cost Estimates for Rajrappa washery (February, 1987), CMPDI.

7. Feasibility Report on "Coking coal import facilities at Vizag port - A techno-economic appraisal (January, 1987), Howe (India) Pvt.Ltd.

8. SAIL Corporate Plan (May, 1987) and other SAIL reports.

9. BSP, RSP and BSL Operational Statistics for 1985-86, 1986-87 - SAIL.

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11. A.K. Singh et.al. "Upgradation of coke quality and improvement in blast furnace productivity under Indian conditions" - IE (I) Journal - MM Vol. 69, September, 1988.

12. Statistics for Iron and Steel Industry in India (January, 1988) SAIL.

13. C. S. Jha Committee Report on Coking coal demand and availability for VII Plan.

14. P.R. Sinha "Supply of coking coal to steel plants" (April, 1989) National Seminar on Modernisation and technology upgradation in Indian mines, Mineral and Metallurgical industry.

15. Reports/documents prepared by Perspective Planning department - CMPDI in connection with working Group on Coal and Lignite for 8th Plan.

16. L.N. Jha et.al. "Effect of coal quality on blast furnace performance with special reference to Bokaro steel plant".

17. Index numbers of wholesale prices (Centre for Monitoring Indian Economy).

18. Revised Cost Estimates for Kedla Washery (January, 1990)

19. Operational Statistics of SAIL steel plants for different years

EXECUTIVE SUMMARY

1. Objectives of the Present Study

The present study has been undertaken to evaluate the relative economics of supply of indigenous clean coking coal with 17% ash content and imported coal with 10% ash content to the different steel plants. The categorywise coking coal demand and supply for the steel plants upto the period 1999-2000 is also to be assessed based on the projections of SAIL and VSP and also based on optimal blend composition for the steel plants.

2. Approach

The availability of prime, medium and semi coking coals for the SAIL and Vishakapatnam steel plants were derived and compared with the demand projections made by SAIL and VSP based on their hot metal production plans. A realistic assessment of hot metal production from SAIL plants based on their past performance and modernisation schemes was carried out and the coal demand was derived based on this assessment. Based on data from three steel plants (BSP, RSP and BSL) regression analysis was done to quantify the optimal coal blend for each of three steel plants with respect to coke properties (M10 index). Based on these optimal blend composition, the categorywise coal requirement was derived. A balance sheet was drawn on the categorywise coking coal requirement and supplies for the different scenarios for the years 1994-95 and 1999-2000. The financial and economic cost of supplies of clean coal from three new mines and washeries were derived from the project reports and compared with delivered cost of imported coking coal at the different steel plants.

3. Methodology

Economic costs have been adopted for comparison since they reflect the real cost to the economy by excluding all transfer payments like duties and taxes from the financial costs. To enable a proper comparative evaluation, the total costs (capital and recurring) have been discounted at 12% to arrive at the net present value of the costs. The cost of clean coal from prime and medium coking coal washeries has been calculated using the discounted value of economic costs and production during the life of the project. Cost of imported coal has been increased by 25% in order to incorporate the foreign exchange scarcity. The economic cost of handling of imported coal has been derived from the project report of a new unloading facility being planned at Vishakapatnam outer harbour in the same manner as for the coal mine and washeries.

4. Sources of supplies for cost analysis

Economic costing has been carried out for the following sources of supplies:

i) prime coking coal from Putki-Baliari mine and Putki washery;

ii) Prime coking coal from Block II opencast mine and Madhuband washery

iii) Medium coking coal from Rajrappa mine and washery;

iv) Medium coking coal from a 2.6 MT/a opencast mine and Kedla washery;

v) Imported coal from new coal unloading facilities at Vishakapatnam port.

5. Economic Evaluation

The capital and recurring costs of the different sources have been taken from project reports. All costs have been updated to

January 1989 based on different cost indices. These financial costs were converted into economic costs by excluding all internal transfers of payments like import duty, excise duty and sales tax. The operating costs were derived from data available in the project reports. Salvage values have not been taken into account for the useful life of assets still left at the completion of the project. The capital and operating costs were arranged in the form of a cash flow statement and the net present value of the costs determined using a discount rate of 12%. The revenue from the sale of middlings is deducted from the total system cost to arrive at the clean coal cost. Based on the net present value of the costs, the cost of clean coal from the four washeries has been calculated and are given below:

npv at 12% discount rate for prime & medium coking coal washeries

Mine + Washery	Total discounted cost (Rs.Million)		Total discounted clean coal production (MT)		Cost of clean coal(Rs./ton)	
Capacity utilisation	100%	85%	100%	85%	100%	85%
1. Putki-Baliari Mine + Putki washery	4281.6	4216.5	3.77	3.21	1134.21	1313.55
2. Block II Mine + Madhuband washery	1649.0	1630.1	2.78	2.37	592.33	688.67
Average cost of prime coking coal	-	-	-	-	**863.27**	**1001.11**
3. Rajrappa mine + Rajrappa washery	-	3129.6	-	5.97	-	523.87
4. 2.6 MT/a opencast mine + Kedla washery	3248.9	3217.5	5.11	4.34	635.79	741.36

Since Putki mine+washery and Block II mine and Madhuband washery appear to be extreme cases so far as cost of clean coal is concerned, it is assumed that the average cost of these two cases will represent the cost of prime coking coal supplies from Jharia coalfield. For

medium coking coal, the combination of a 2.60 MT/a opencast mine i Hararibagh area and Kedla washery is taken as representative of futur medium coking coal washeries. For the opencast mine, the cost figure of Rajrappa opencast project has been taken for convenience. The cos of clean coal from Kedla washery is taken for comparison wit imported coal.

6. Coking coal import from Australia

The delivered cost of imported coal at Vishakapatnam port i taken as US$ 70 per tonne (coal price - $ 52/tonne and ocean freight 18/tonne). The net present value of the total costs of coal handlin arrangement at new unloading facility at Vishakapatnam port is derive from the project report. The costs have been worked out separatel taking costs without premium on foreign exchange component (FEC) an with 25% premium on FEC. The net present values and the cost of coa handling are as follows:

npv at 12% discount rate for new general cargo berth (Economic)

	Total discounted cost(Rs.Million)	Total discounted coal handled (MT)	Cost per tonne o coal handling (Rs
Economic cost	2021.394	20.069	100.72
Economic cost (with 25% on FEC)	2064.873	20.069	102.89

The economic cost of imported coal at the port works out a follows:

Cost of imported coal at port (Economic)

(Rs. per tonne)

	No premium on FEC	25% premium on FEC
C F value of coal	1155.00	1443.75
Port handling charges	100.72	102.89
Total cost of coal	1255.72	1546.64

7. Comparison of delivered economic cost of indigenous and imported coal at steel plants

All prime coking coal is supplied from Jharia coalfield and medium coking coal (except from Nandan washery) is supplied from Jharia, Bokaro and Ramgarh coalfields. For convenience in assessing rail transportation cost, the source of indigenous supplies is taken as Dhanbad. Imported coal can be supplied from Vishakapatnam, Paradip and Haldia ports. The nearest port from the steel plant is taken as the source of supply and the port handling cost is notionally assumed the same for all the ports (as derived for Vishakapatnam port). The economic cost of rail transportation is taken as 20 paise per tonne kilometer (based on RITES studies). The rail transportation cost of coking coal supplies to steel plants is given in the below:

Rail transportation cost of coking coal to steel plants
(Economic cost) Rs/tonne)

Steel Plants	BSP	RSP	BSL	DSP	IISCO	VSP
Supply Source: Dhanbad	155.60	67.40	10.00	20.20	12.80	198.80
Vishakapatnam	110.20	131.40	188.80	202.20	192.80	-
Paradip	146.60	101.80	112.60	127.00	105.60	-
Haldia	175.20	87.00	77.80	59.60	64.80	-

The delivered economic cost of prime, medium and imported coal at the steel plants is calculated based on the above figures. Finally, the cost of indigenous prime and medium coking coals is multiplied by a factor of 1.4 for comparison with the cost of imported coal. This factor has been used by CMPDI for conversion of indigenous coking coal to equivalent imported coal, and reflects the superior quality of imported coal. The delivered economic cost of coal at steel plants is given below.

Delivered cost of coal at steel plants (Economic)
(Economic cost) (Rs./tonne)

Steel Plant	Cap. Utili- zation	Prime coking Cost	Prime coking cost x 1.4	Medium coking Cost	Medium coking cost x 1.4	Imported coal No premium on FEC	Imported coal 25% premium on FEC	
BSP	(100%)	1018.87	1426.42	791.39	1107.15	1365.92	1656.84	(Viza
	(85%)	1156.71	1619.39	896.96	1255.74			
RSP	(100%)	930.67	1302.94	703.19	984.47	1387.12	1678.04	(Viza
	(85%)	1068.51	1495.91	808.76	1132.26	1357.52	1648.44	(Parad
BSL	(100%)	873.27	1222.58	645.79	904.11	1333.52	1624.44	(Haldi
	(85%)	1011.11	1415.55	751.36	1051.90			
DSP	(100%)	883.47	1236.86	655.99	918.39	1315.32	1606.24	(Haldi
	(85%)	1021.31	1429.83	761.56	1066.18			
IISCO	(100%)	876.07	1226.50	648.59	908.03	1319.72	1610.64	(Haldi
	(85%)	1013.91	1419.47	754.16	1055.82			
VSP	(100%)	1062.07	1416.90	834.59	1168.43	1255.72	1546.64	(Viza
	(85%)	1199.91	1679.87	940.16	1316.22			

8. Conclusions

1. Economic cost of coal supplies:

a) Prime coking coal - 85% mine and washery capacity utilisation

i) The economic cost of prime coking coal at BSP is higher than the cost of imported coal (without premium on FEC) and marginally lower than the cost of imported coal (with 25% premium on FEC)

ii) At RSP, BSL, DSP and IISCO, the economic cost of prime coking coal is higher than the cost of imported coal (without premium on FEC) from the nearest port, but it is lower than the cost of imported coal (with 25% premium on FEC)

iii) At VSP, the cost of prime coking coal is substantially higher than the cost of imported coal (without and with premium on FEC).

b) **Prime coking coal - 100% mine and washery utilisation**

i) At BSP, the cost of prime coking coal is higher than the cost of imported coal (without premium on FEC) but lower as compared to the cost of imported coal (with 25% premium on FEC)

ii) At RSP, BSL, DSP and IISCO, the costs of prime coking coal is lower than the cost of imported coal (without premium on FEC) and substantially lower than the cost of imported coal (with 25% premium on FEC).

iii) At VSP the cost of prime coking coal is much higher than the cost of imported coal (without premium on FEC) but lower than the cost of imported coal (with premium on FEC).

c) **Medium coking coal - 85% mine and washery capacity utilisation**

i) The economic cost of medium coking coal at BSP, BSL, RSP, DSP, IISCO is substantially lower than the cost of imported coal (with and without premium on FEC);

ii) At VSP, the cost of medium coking coal is higher than the cost of imported coal (without premium on FEC) but is considerably lower than the cost of imported coal (with 25% premium on FEC)

d) **Medium coking coal - 100% mine and washery capacity utilisation**

i) The economic cost of medium coking coal at all the steel plants is substantially lower than the cost of imported coal (with without premium on FEC).

e) **Prime coking coal from Putki washery**

The economic cost of prime coking coal from Putki washery at different steel plants is given below:

Economic cost of prime coking coal from Putki washery (Rs./Tonne)

	BSP	RSP	BSL	DSP	IISCO	VSP
1) 85% cap.utilisation	1469.15	1380.95	1323.55	1333.75	1326.35	1512.35
2)100% cap.utilisation	1289.81	1201.61	1144.21	1154.41	1147.01	1333.01

When the cost of coal is multiplied by the factor 1.43 for comparison with imported coal, the cost of prime coking coal from Putki washery becomes very high compared to the cost of imported coal. Since Putki mine and washery are representative of future underground mine in the prime coking coal sector, the whole issue of investment in such mines needs to be fully examined. Moreover, the cost of environmental effects and rehabilitation is probably not fully reflected in the project costs.

9. **Optimal blend composition for BSP, RSP and BSL**

In order to quantify the optimal coal blends with respect to coke properties, the strength (M_{10} index) was correlated to the various constituents in the blend in the three steel plants using the Merrick model. The results are as follows:

Figure in percentage

Steel Plant	Indigenous Prime	Indigenous Medium+Semi	Imported
BSP	25	35	40
BSL	30	50	20
RSP	28	40	32

Monthwise data for three years (1985-86 to 1987-88) was used in the analysis. It was observed that the ash percent in the coal blend during these three years was less compared to the previous years i

all the three plants. In a statistical sense, these results are of limited value since extrapolation of trends and correlations cannot be made due to the narrow ranges of all the variables. So at best, the results can only be taken as indicative.

Poor coke strength and high ash coke are well known limitations for high productivity in Indian blast furnaces. Coke properties can be improved by reducing ash in coal and by a change in coal mix (through blending with imported coal). A perusal of the blast furnace performance data for the last 10 years for BSP, BSL and RSP show that with lowering of the ash percent in the coal blend, the coke rate has been going down especially during the last 3-4 years. This reduction in ash content in the blend has been brought about through increased share of imported coal in the blend and decreasing trend in ash percent in indigenous supplies.

10. Coking coal supplies to SAIL plants and VSP in 1994-95 and 1999-2000

Three scenarios are evaluated for coking coal supplies to the steel plants. In all the cases, some amount of imported coal has been taken as essential for improving the quality of coal blend. This will result in not only reducing the ash percent in the coal blend but more importantly, coke characteristics will improve significantly. The share of imported coal varies from 10% to 25% in different plants.

Scenario 1: SAIL hot metal production and categorywise distribution based on SAIL plan and VSP as per Working Group

The coking coal requirements based on SAIL and VSP plans for hot metal production and category-wise coal distribution show that there will be surplus availability of prime coking coal ranging from 0.98 MT to 2.27 MT and a large deficit of about 2.5 MT in medium+semi coking

coal. This results in increased import of coking coal.

<u>Scenario 2</u>: SAIL - realistic assessment of hot metal production and categorywise distribution as per SAIL Plan. VSP as per Working Group

The coking coal demand based on realistic assessment of hot metal production and categorywise distribution as per SAIL plan for 1994-95 and for VSP based on Working Groups report show that there will be surplus in the availability of prime coking coal ranging from 2.43 MT to 3.39 MT under different assumptions. Medium and semi coking availability will be in deficit varying from 0.30 MT to 0.67 MT in 1994-95 and 0 to 0.85 MT in 1999-2000.

<u>Scenario 3</u>: SAIL - realistic assessment of hot metal production and categorywise distribution as per optimal blend. VSP as per Working Group

The coking coal demand based on realistic assessment of hot metal production and categorywise distribution as per optimal blend derived for BSP, BSL and RSP again shows that there will be surplus in availability of prime coking coal ranging from 2.85 MT, 3.8 MT. There will be marginal surplus or deficit in availability of medium+semi coking coal under different assumptions.

The summarised results of coal demand-supply balance for the three scenarios and the imported coal requirements based on quality considerations are given in the table below. Column (a) figures take into account IISCO renovation and column (b) figures include IISCO without renovation. For 1999-2000, two situations have been assumed: 1 - coke rate as per SAIL plan (15% ash in coalblend) and 2- coke rate is the average between 1989-90 and 1990-2000 figures.

Coal Demand - Supply Sheet for SAIL and VSP

(Million Tonnes)

	1994-95		1999-2000			
	(a)	(b)	2(a)	2(b)	1(a)	1(b)
Indigenous coal						
Surplus/deficit	(-)1.45		-	-		
Scenario-1	-	-	-		(-)0.27	-
Scenario-2	1.97	2.81	1.58	2.62	2.24	3.45
Scenario-3	2.75	3.62	2.44	3.67	3.08	4.29
Imported coal requirement						
Scenario-1	5.50	-	-	-	6.22	-
Scenario-2	3.68	3.59	3.92	3.79	3.74	3.61
Scenario-3	4.43	4.34	4.75	4.62	4.53	4.40

If on economic conditions, Putki washery project is shelved, the surplus availability of prime coking coal is reduced by 1.04 MT in 1994-95 and by 1.27 MT in 1999-2000. The position then becomes as follows:

Coal Demand Supply Balance for SAIL and VSP (without Putki)

(Million Tonnes)

Indigenous coal						
Surplus/deficit						
Scenario-1	(-) 2.49	-	-	-	(-)1.54	-
Scenario-2	0.93	1.77	0.31	1.35	0.97	2.18
Scenario-3	1.71	2.58	1.17	2.40	1.81	3.02

A perusal of the above results shows that scenario-2 is the best option on the basis of categorywise distribution of coal. After deducting the requirements of Durgapur coke oven plant and FCI which is projected at 0.25 MT per annum, the position for scenario-2 is given below:

Scenario 2: Coal Demand-Supply Balance

(Million Tonnes)

	1994-95		1999-2000	
	(a)	(b)	(a)	(b)
Surplus availability of indigenous coal				
- Without Putki washery	0.68 (4%)	1.52 (9%)	0.06 (-)	1.10 (6%)
- With Pukti washery	1.72(10%)	2.56(15%)	1.33 (8%)	1.37 (13%)

Figures in bracket indicate percent share of total coal availability

In scenario-2, the categorywise distribution is based on SAIL plan (figures for 1994-95). The import quantity is the minimum on quality consideration and the surplus availability of indigenous coal is also minimum. The average share of imported coal in the blend for SAIL steel plants works out to 20.6% in 1994-95 and 20.9% in 1999-2000 under situation 2. For 1999-2000, situation 2 is recommended since the surplus of indigenous coal is less under this assumption. Without Putki washery the surplus availability is only 4% in 1994-95 and nil in 1999-2000 (assuming IISCO renovation).

It is also projected that the M_{10} index will be below 10 with this distribution and if pre-carbonisation techniques are adopted in the plants, the M_{10} index may go down to 8.

If the surplus prime coking coal is consumed in the nearby steel plants, the import requirement of coking coal will be correspondingly reduced. This will result in a change in the blend composition which may affect coal - hot metal ratio and blast furnace productivity.

11. **Recommendations**

a) From an economic point of view it is recommended that:

i) BSP should use imported coal upto the projected level of 25% in the coal blend;

ii) VSP should use imported coal to the extent of maximum availability

iii) Imported coal requirement of RSP, DSP, IISCO and BSL should be met from Haldia/Paradip ports;

iv) Due to the high cost of clean coal from Putki washery investment in Putki mine and washery should be critically examined. This also becomes relevant since availability of prime coking coal is surplus in 1994-95 and 1999-2000 under the different scenarios. The whole issue of future investment in underground prime coking coal mines and washery need to be fully examined before investment decisions are taken.

b) The supply scenarios are based on a realistic assessment of hot metal production from SAIL plants based on their past performance and planned modernisation schemes.

From supplies point of view it is recommended that:

i) Since sufficient capacity already exists in prime coking coal sector (including Madhuband washery but excluding Putki washery) availability of surplus prime coking coal should be utilised in BSL, DSP, RSP, IISCO; to meet the shortfall in medium coking coal supplies.

ii) Scenario - 2 is recommended for gradewise distribution since the quantity of imported coal and the surplus availability of indigenous coal is the minimum. The overall surplus under scenario-2, without Putki washery is 4% only in 1994-95 and nil in 1999-2000 after taking into account IISCO modernisation. Even without IISCO modernisation the surplus availability is less than 10% and can be taken as an insurance against shortfall in supplies.

iii) Since the cost of medium and semi coking coal ar comparatively less, their share can be increased upto 50% i the coal blend without affecting the quality of coke. Moreover, since there is a deficit in medium coking coal, shelf of project reports for medium coking coal mine an washeries should be prepared and investment decisions can b taken if and when demand increases.

c) In the metallurgical sector, initially the coking coals had been characterised by parameters such as volatile matter, ash content, free swelling index, LTGK coke type etc. New coal quality parameters such as petrographic constituents, fluidity etc. are now being considered. For identifying the significant coal quality parameters, which influence changes in coke quality, it is necessary to carry out detailed characterisation of all the coals that are used as raw materials for carbonisation and also carry out carbonisation studies for evaluation of coke quality parameters corresponding to coal quality parameters.

CHAPTER 1
Steel Consumption and Demand

1.1 Introduction

Commercial production of steel started in India in 1907 when the Tata Iron and Steel Company came into existence at Jamshedpur. In 1919 Indian Iron and Steel Company (IISCO) was established at Burnpur and in 1923 Mysore Iron and Steel Works came into operation at Bhadravathi in Mysore. Rapid development of steel industry began only during the second Five Year Plan. Three integrated steel plants of one million tonne capacity each were set up in the public sector at Rourkela, Bhilai and Durgapur. The subsequent expansion of these three public sector plants was followed by the installation of another integrated steel plant at Bokaro. The growth in the installed capacity of the steel plants at different stages is given in **Table 1**.

Table 1: Growth in Installed Capacity of Steel Plants
(Million Tonnes)

Plant	Installed Late 1940's	Capacity of Mid 1960's	Crude Steel March 1989
Private Sector			
- TISCO	1.7	2.0	2.0
- IISCO	0.5	1.0	-
- Mini Steel Plants	1.0	1.6	3.0
Public Sector			
- IISCO	-	-	1.0
- RSP	-	1.0	1.8
- BSP	-	1.0	4.0
- DSP	-	1.0	1.6
- BSL	-	-	4.0
Total	3.2	7.6	17.4

Source: SAIL Corporate Plan (May 1987) & other reports.

The development of the Indian steel industry has been based on two broad technological routes:

i) Coke-ovens-blast furnace-openhearth basic oxygen furnace referred to as integrated steel plant; and

ii) Scrap based Electric Arc Furnace (EAF) steel making - also referred to as the secondary sector.

All the integrated steel plants are located in the eastern and central part of the country and they draw most of their raw materials from captive sources except coking coal for which they are dependent on the coal sector. TISCO, however, has captive coal mines. The integrated steel plants have also been importing coking coal. Besides the existing integrated plants, a new integrated steel plant with an annual capacity of 3.40 MT in the government sector is under construction at Vishakapatnam.

The secondary sector comprises of 212 mini-steel plants scattered all over the country having a total installed capacity of about 5.00 million tonnes and it plays a significant role in meeting part of the country's steel demand. The secondary sector also has a large number of re-rollers with an estimated capacity of 17 million tonnes. These rerollers largely work as conversion agents for mini steel plants and TISCO. The mini steel plants are dependent primarily on scrap obtained from indigenous sources as well as through imports. They are totally dependent for their power requirement on state electricity boards.

The secondary sector also expanded fast in the early 70's but later its performance declined. In the Seventh Plan period, the

integrated steel plants have shown improved performance but the situation in the secondary sector remains unsatisfactory. During the initial years of growth of the steel industry, the integrated steel plants exhibited a good performance. But this could not be sustained over a long time horizon. The gap between the performance indices of Indian steel plants and the steel plants in the developed countries widened over time due to fast technological developments abroad and stagnant or marginally deteriorating technological state in India.

1.2 Steel Production and Consumption

The hot metal which is produced in the blast furnace can either be used for casting of pig iron or for making ingot steel. Similarly ingot steel can either be converted into saleable finished steel or into semis (blooms, billets and slabs) which are sold to re-rollers. Table 2 gives the production and availability of crude steel from 1965-66 onwards:

Table 2: Production & Availability/ Consumption of Steel

(Million Tonnes)

Year	Production	Import	Export	Consumption
1965-66	4.4	0.7	0.1	5.0
1970-71	4.5	0.5	0.5	4.6
1975-76	5.8	0.5	0.8	5.5
1980-81	6.8	1.0	-	7.8
1984-85	8.7	1.7	0.2	10.2
1985-86	9.0	2.0	0.3	10.7
1986-87	10.5	1.6	-	12.1
1987-88	11.4	1.4	-	12.8
1988-89 (Est.)	12.3	1.3	-	13.6

Source: SAIL

1.3 Demand Issues

Since, under a regime of import control, figures of past availability do not indicate the volume of demand, estimates of the future demand for steel are usually prepared based on certain assumptions, namely, by assuming a rate of growth of the economy, the likely rate of growth of industries using steel, and likely input-output relationship in the economy, especially with reference to the use of steel. Consumers demand should normally control production and product-mix of the industry. This task is difficult in an economy in which the per capita consumption of steel is among the lowest in the world and moreover only 10% of the population use 90% of steel consumed. Agricultural production linked with monsoon affects general economy significantly influencing government spending and thereby steel consumption. Therefore, it is possible that the true latent demand has not been touched. Majority of Indian experts foresee a steady increase in the demand for steel in the future. Several studies have been carried out regarding the future demand for steel. Apart from the forecasts of the Planning Commission, two particularly comprehensive estimates made in this connection are by the National Council of Applied Economic Research (NCAER) and Steel Authority of India (SAIL).

Different methodologies have been adopted by SAIL, NCAER and Planning Commission for projecting the demand for steel products in the terminal years of 7th, 8th and 9th Plans. The detailed estimates of demand as presented by different agencies are summarised in **Table 3** alongwith the final consensus figures of the Working Group on Iron and Steel for the 8th Plan. The details are given in **Annexure 1.1.**

Table 3: **Steel Demand Projection by Different Agencies**
(Million Tonnes)

	1989-90			1994-95			1999-2000		
	SAIL	NCAER	WG	SAIL	NCAER	WG	SAIL	NCAER	WG
Finished Steel	14.28	15.09	14.80	18.79	20.56	20.07	24.96	28.40	27.02

Source: SAIL Corporate Plan (1987)
Working Group on Iron & Steel Demand for 8th Plan
(Sub Group Report 1989)

It can be observed from the table that the steel industry will be entering a phase of rapid growth in the period 1990-2000. Nearly 1 MT additional saleable steel capacity is to be created every year to meet the projected demand. With the assumption that the growth rate during the 10th Plan period would be similar to that of the 9th plan period the finished steel demand in 2004-05 would be around 36 million tonnes.

1.4 Supply Options

The various options available to the steel industry for capacity expansion are:

i) expansion/modernisation of the existing integrated steel plants;

ii) expansion of the secondary sector; and

iii) setting up of new integrated steel plants.

Studies conducted by SAIL and other agencies established that through technological upgradation and other organisational measures, it would be possible to improve the techno-economic indices of existing plants. Apart from the only one new integrated steel plant, currently under construction, which is likely to come into operation in 1990-91, no new integrated steel plant has been planned for the current decade. Bhilai and Bokaro have completed their expansion

programmes to 4 MT ingot steel capacity. The expansion of TISCO to 2.60 MT capacity is under progress. Besides these, the revamping and expansion programme of DSP is under implementation but revamping and expansion of IISCO and RSP are only in the preliminary stages.

1.5 Hot Metal Production and Blast Furnace Productivity

Because of strong global competition the steel industry in certain developed countries has been able to maintain economic viability through achievement of continuous improvement in performance levels. Technology has played a vital role in this effort. As a result of these technological developments, the developed countries, especially, Japan have radically improved their techno-economic indices. In contrast to the developments abroad, SAIL plants have remained relatively technologically undeveloped and their techno-economic performance indicators are far below that of developed countries. The steel plants are operating at very low productivity levels with high specific consumption rates for most of the raw materials. The overall energy consumption is very high as compared to any modern plant. Some important parameters of blast furnace practice in India compared with those abroad are given in the Table 4.

Table 4: Comparison of Important Operating Indices of Indian Blast Furnaces vis-a-vis Those Abroad

Parameters	Unit	India	Efficient Furnaces Abroad
Productivity	$t/m^3/day$	0.6-1.1	1.8-2.5
Carbon rate	kg/thm	510-720	380-470
Energy consumption upto hot metal state	Gcal/thm	6.0-6.5	4.0-4.5
Blast temperature	^oC	600-1000	1100-1350
High top pressure	kg/cm^2	0-14	1.5-2.5
Total pressure drop	kg/cm^2	1.0-1.4	0.9-1.1
Oxygen enrichment	%	-	2-5
Auxiliary fuel injection	kg/thm	-	30-50
Shaft efficiency		0.7-0.8	0.94-0.98
Hot metal temperature	^oC	1250-1425	1450-1520
CO/CO_2 in top gas		1.4-1.5	0.9-1.2
Si in hot metal	%	1.2-1.5	0.15-0.8
Slag rate	kg/thm	400-700	230-280
Al_2O_3	%	22-25	12-15
$CaO/Si\backslash O_2$	%	0.85-1.08	1.10-1.15
Sinter in burden	%	0-70	85-100

Source: IE (I) Journal - MM, Vol. 69, September 1988

One of the reasons for such a low efficiency of operation is adverse raw material characteristics peculiar to Indian conditions such as:

i) High ash coking coal with unfavourable washing characteristics;

ii) High alumina to silica ratio of iron ore;

iii) High insoluble content of fluxes, particularly in the SMS grade.

Another cause of poor production performance has been the low levels of plant availability.

The production of hot metal in the integrated steel plants has to increase substantially to meet the increasing demand for steel. Since 1984-85, there has been a steady increase in production from SAIL steel plants. Vishakapatnam steel plant is expected to start producing hot metal from 1990-91. The steel plantwise hot metal production from 1980-81 to 1989-90 are given in the Table 5.

Table 5: Hot Metal Production

(Million Tonnes)

Year	SAIL	TISCO	TOTAL
1980-81	6.73	1.65	8.38
1981-82	7.73	1.77	9.50
1982-83	7.69	1.79	9.48
1983-84	7.37	1.75	9.12
1984-85	7.44	1.81	9.24
1985-86	8.28	1.75	10.03
1986-87	8.50	1.94	10.44
1987-88	8.55	1.90	10.75
1988-89	9.64	2.00	11.64
1989-90 (Est)	9.74	2.24	11.98

Source: SAIL and CMPDI

1.6 Blast Furnace Operation and Corporate Plan

The monthly average blast furnace productivity in different steel plants ranges between 0.7 and 1.1 t/m^3/day. Some of these furnaces have attained, at times as high a productivity as 1.35 t/m^3/day with the same inputs. This indicates the inherent technical potential of these furnaces. An analysis of blast furnace operation of SAIL plants since the beginning of 70's indicates that the blast furnace availability at full wind varied between as low as 68% in one plant to 91.6% in another. However, the Corporate Plan Document of SAIL has assumed a figure of 95% for blast furnace availability in its

projections. The total useful volume in 30 blast furnaces in the country (including TISCO) is around 39,000 m^3. Even at a modest productivity level of 1.0 $t/m^3/day$, it should be possible for the steel plants to produce around 13.5 MT of hot metal per year. Moreover introduction of new technologies and improvement of feed materials will result in improving the productivity of blast furnaces.

The SAIL and TISCO have prepared a "Corporate Plan" and a detailed "Technology Plan" which envisages implementation of several measures upto 2000 AD to improve the plants performance. In the technology plan, due emphasis has been given to improvement in coke quality as well as blast furnace productivity. Some of the measures planned and under implementation in SAIL steel plants are detailed below:

(a) Content of lump size in blast furnace coke which was usually in the range of 30-35% at Bhilai (BSP) has been brought down to less than 10% by modifying the design and configuration of cutter teeth and changing the materials of construction. Use of blast furnace coke with reduced content of lump size has resulted in considerable reduction in coke rate (by 7.8%) and increase in blast furnace productivity (by 8.6%). This has more than offset the loss due to increased generation of fines)by 4.9%);

(b) After extensive laboratory and pilot oven investigations, technology of group-wise crushing of coal has been evolved which improves M10 index of coke by about 1.5 point;

(c) Studies have been conducted to work out the matching optimum specifications of imported coal. Models were also developed to

predict the optimum use of imported coal. Judicious use of imported coal has resulted in distinct improvement in coke quality and reversed the deteriorating trend;

(d) Actions have been initiated to introduce partial briquetting of coal charge (PBCC) technology and Computerized Combustion Control System (CCCS) at Bhilai Steel Plant;

(e) Coal dust injection system has been introduced in BF-2 of Bhilai Steel Plant;

(f) Lime dust injection system, developed by R & D Centre, SAIL has been introduced in BF-1 at Durgapur (DSP);

(g) External desulphurization of hot metal has been introduced at Rourkela (RSP);

(h) Movable throat armour has been introduced in one blast furnace each at BSP, RSP and IISCO (Burnpur);

(i) Steps have been taken to modify the blast furnace stoves as per the Hoogavens system to raise the hot blast temperature above 1000 deg.C.

(j) Pre-skip sinter screening is being introduced at RSP;

(k) BF-7, recently commissioned at BSP, represents a model blast furnace in India, having P-W top for burden distribution, conveyorised feeding system, cast house slag granulation, fully computerised process control system, etc.

These measures, once implemented would lead to among other things, increase in hot metal production and blast furnace productivity. The projected production of hot metal in 1990-91 to 1994-95 and 1999-2000 are given in **Table 6** below:

Table 6 : Hot Metal Production Projection

(Million Tonnes)

Year	SAIL	TISCO	VSP	Total
1989-90 (Est)	9.74	2.24	-	11.98
1990-91	11.95	2.30	1.40	15.65
1991-92	12.13	2.55	2.55	17.23
1992-93	12.53	2.60	3.40	18.53
1993-94	13.46	2.60	3.40	19.46
1994-95	15.06	2.60	3.40	21.06
1999-2000	19.65	2.60	3.40	25.65

Source: SAIL Corporate Plan (May 1987)
CMPDI

1.7 Critical Assessment of SAIL's Hot Metal Production Plan

A critical assessment of the projections of hot metal production by SAIL plants has been made based on individual plants blast furnace operation in the last decade (1980-81 to 1989-90).

The following **Tables 7 to 11** give the blast furnace capacity, useful volume, hot metal production, capacity utilisation, blast furnace productivity, ash % in coal blend and coke rate for each steel plant during the period 1980-81 to 1989-91. The tables also give the projected hot metal production and capacity additions based on the SAIL's Corporate Plan document. **Figure 1** gives the relationship between ash percent in coal blend and blast furnace productivity for the different steel plants. **Figures 2 and 3** depict the average capacity utilisation of blast furnaces in each plant during the last decade.

Table 7: BSP: Past Performance & Future Projection (as per SAIL)

	Installed Capacity (MT)	BF Volume (cu m)	Hot Metal Prodn (MT)	%age Utiliza-tion(%)	BF Productivity (T/cu m/yr)	Ash % in Coal (%)	Coke Rate (kg coal/ kg HM)
1980-81	2.97	8256	2.214	74.5	268.17	20.1	0.837
1981-82	2.97	8256	2.377	80.0	287.91	19.7	0.842
1982-83	2.97	8256	2.33	78.5	282.22	18.7	0.823
1983-84	2.97	8256	2.124	71.5	257.27	20	0.816
1984-85	2.97	8256	2.339	78.8	283.31	19.3	0.787
1985-86	2.97	8256	2.604	87.7	315.41	17.1	0.723
1986-87	2.97	8256	2.51	84.5	304.02	16.7	0.709
1987-88	2.97	8256	2.556	86.1	309.59	16.7	0.729
1988-89	4.08	10256	3.306	81.0	322.35	16.1	0.69
1989-90	4.08	10256	3.494	85.6	340.68	16.3	0.69
1990-91	4.08	10256	4.08	100.0	397.82		
1994-95	4.08	10256	4.41	108.1	429.99	17.0	0.69
1999-2000	4.3	10942	5.12	119.1	467.92	15.0	0.61

Source: SAIL Corporate Plan and other documents.

Table 8: Bokaro-Past Performance & Future Projection (as per SAIL)

	Installed Capacity (MT)	BF Volume (cu m)	Hot Metal Prodn (MT)	%age Utiliza-tion(%)	BF Productivity (T/cu m/yr)	Ash % in Coal (%)	Coke Rate (kg coal/ kg HM)
1980-81	2.735	6000	1.678	61.4	279.67	21.81	0.777
1981-82	2.735	6000	2.192	80.1	365.33	21.05	0.759
1982-83	2.735	6000	2.194	80.2	365.67	20.64	0.752
1983-84	2.735	6000	2.275	83.2	379.17	20.42	0.731
1984-85	2.735	6000	2.4	87.8	400.00	20.04	0.709
1985-86	2.735	6000	2.524	92.3	420.67	18.43	0.728
1986-87	4.58	10000	2.813	61.4	281.30	17.82	0.706
1987-88	4.58	10000	3.123	68.2	312.30	17.77	0.679
1988-89	4.58	10000	3.22	70.3	322.00	16.9	0.666
1989-90	4.58	10000	3.269	71.4	326.90	16.4	0.668
1990-91	4.58	10000	4.62	100.9	462.00		
1994-95	4.58	10000	4.72	103.1	472.00	17.0	0.69
1999-20	4.58	10000	5.25	114.6	525.00	15.0	0.61

Table 9: RSP-Past Performance & Future Projection (as per SAIL)

	Installed Capacity (MT)	BF Volume (cu m)	Hot Metal Prodn (MT)	%age Utilization(%)	BF Productivity (T/cu m/yr)	Ash % in Coal (%)	Coke Rate (kg coal/ kg HM)
1980-81	1.6	5075	1.227	76.7	241.77	19.41	0.875
1981-82	1.6	5075	1.336	83.5	263.25	18.87	0.835
1982-83	1.6	5075	1.203	75.2	237.04	18.52	0.89
1983-84	1.6	5075	1.15	71.9	226.60	20.65	0.885
1984-85	1.6	5075	1.139	71.2	224.43	20.02	0.853
1985-86	1.6	5075	1.229	76.8	242.17	18.28	0.811
1986-87	1.6	5075	1.223	76.4	240.99	17.56	0.792
1987-88	1.6	5075	1.212	75.8	238.82	17.04	0.764
1988-89	1.6	5075	1.25	78.1	246.31	16.88	0.736
1989-90	1.6	5075	1.242	77.6	244.73	17.08	0.729
1990-91	1.6	5075	1.35	84.4	266.01		
1994-95	2.2	7075	2	90.9	282.69	17.0	0.83
1999-20	2.2	7075	3.18	144.5	449.47	15.0	0.70

Table 10: DSP-Past Performance & Future Projection (as per SAIL)

	Installed Capacity (MT)	BF Volume (cu m)	Hot Metal Prodn (MT)	% age Utilization(%)	BF Productivity (T/cu m/yr)	Ash % in Coal (%)	Coke Rate (kg coal/ kg HM)
1980-81	1.7	5723	0.821	48.3	143.46	21.96	1.017
1981-82	1.7	5723	1.023	60.2	178.75	22.13	0.957
1982-83	1.7	5723	1.056	62.1	184.52	21.78	0.901
1983-84	1.7	5723	0.978	57.5	170.89	22.36	0.935
1984-85	1.7	5723	0.884	52.0	154.46	21.97	0.883
1985-86	1.7	5723	1.064	62.6	185.92	21.3	0.869
1986-87	1.7	5723	1.125	66.2	196.58	20.3	0.899
1987-88	1.7	5723	1.138	66.9	198.85	19.49	0.89
1988-89	1.7	5723	1.096	64.5	191.51	19.7	0.856
1989-90	1.7	5723	1.062	62.5	185.57	18.68	0.865
1990-91	1.7	5723	1.2	70.6	209.68		
1994-95	1.7	5723	1.885	110.9	329.37	17.0	0.78
1999-20	1.7	5723	2.4	141.2	419.36	15.0	0.70

Table 11: IISCO-Past Performance & Future Projection (as per SAIL)

	Installed Capacity (MT)	BF Volume (cu m)	Hot Metal Prodn (MT)	%age Utilization(%)	BF Productivity (T/cu m/yr)	Ash % in Coal (%)	Coke Rate (kg coal/kg HM)
1980-81	1.3	3340	0.788	60.6	235.93	21.71	1.136
1981-82	1.3	3340	0.8	61.5	239.52	22.2	1.151
1982-83	1.3	3340	0.912	70.2	273.05	21.92	1.072
1983-84	1.3	3340	0.844	64.9	252.69	22.22	1.054
1984-85	1.3	3340	0.677	52.1	202.69	22.31	1.188
1985-86	1.3	3340	0.862	66.3	258.08	22.04	1.056
1986-87	1.3	3340	0.824	63.4	246.71	20.81	1.015
1987-88	1.3	3340	0.818	62.9	244.91	19.28	0.991
1988-89	1.3	3340	0.768	59.1	229.94	19.23	1.023
1989-90	1.3	3340	0.669	51.5	200.30	19.3	1.021
1990-91	1.3	3340	0.95	73.1	284.43		
1994-95	1.73	4500	1.6	92.5	355.56	17.0	0.74
1999-20	1.73	4500	2.2	127.2	488.89	15.0	0.74

1.8 An analysis of the past performance of the blast furnace operations is given in the following paragraphs.

a. No dependence of blast furnace productivity or hot metal production or capacity utilisation on coal quality, except for Bokaro Steel plant where blast furnace productivity decreases with decreasing ash percentage in coal. For the Rourkela and Bhilai Steel plants, blast furnace productivity increases as ash content decreases but then becomes constant for ash content less than 18%. In the case of IISCO and DSP, there does not seem to be any statistically significant variation in blast furnace productivity with ash content.

On the whole, there does not seem to be any effect of coal quality on BF productivity once the ash percentage is less than 18%.

b. There does not seem to be any consistent pattern in the production profile. Production increases considerably within an year or two of the commissioning of a new blast furnace and then levels off to a more or less constant value.

BSL

In the case of Bokaro, the capacity utilisation steadily increased from 75% to 92% during the period from 1980-81 to 1985-86 (an annual compounded increase of 4%) and then suddenly dropped to 61% in 1986-87 with the commissioning of a new blast furnace which increased the installed capacity by 67%. Subsequently it has then increased to 71% by 1989-90: an annual compounded increase of about 5%. Therefore the plant can be expected to attain a maximum peak capacity utilisation of about 95% in 1994-95 and 100% in 1999-2000. Additional capacity initially has a utilisation factor of 15% and takes about 9 years to reach peak utilisation.

BSP

Bhilai Steel Plant has exhibited rather erratic performance (1980-81 to 1981-82) and then slipped to 71% in the next two years. Thereafter, it increased again (to a peak at 88% in two years) and maintained an average of 85% till 1989-90. Surprisingly, additional capacity installation (during 1987-88) did not lower the utilisation factor significantly: it went down to 81% in 1988-89 and then increased to 85% by 1989-1990. BSP can be expected to maintain a minimum long-term average capacity utilisation factor of 90% and a maximum of 95% by 1994-95 and 100% in 1999-2000.

RSP

Rourkela Steel Plant has shown a steady utilisation factor of about 75% since 1985-86 : the year from which coal ash has been 18% or less. There is no indication of how the plant performance would be affected if new capacity is installed, but it can be reasonably expected that a minimum peak utilisation factor of 80% and a maximum

of 85% can be achieved. A new blast furnace of 2000 m^3 capacity is planned to be added in the 9th plan period. New capacity is assumed to reach peak utilisation in 5 years.

DSP AND IISCO

The performance of Durgapur Steel Plant and IISCO have been traditionally poor. Utilisation factors have oscillated between 50 and 65% in 4 to 5 year cycles. Even though, no additional capacity is envisaged at DSP, modernisation schemes are under implementation. Therefore, a long term utilisation factor of a minimum of 80% and a maximum of 85% can be assumed for DSP. Complete renovation of IISCO is planned and if this occurs, the utilisation factor may touch the 95% mark. However, renovation is dependent on availability of resources. If renovation does not take place, a utilisation factor of 50% (minimum) and 65% (maximum) is assumed.

1.9 Based on the analysis of the individual steel plants, the expected hot metal production in 1994-95 and 1990-2000 are as follows:

Table 12: Hot Metal Production Projection Based on Blast Furnace Capacity Utilisation

(Million Tonnes)

Item	Bhilai	Bokaro	Rourkela	Durgapur	IISCO With Reno.	IISCO Without Reno	SAIL With IISCO Reno.	SAIL Without IISCO Reno.
1994-95								
Installed Cap.(MT)	4.08	4.585	1.60	1.70	1.73	1.30	13.695	13.265
Cap.Utilisation factor(%)								
- Max.	90	100	85	80	80	65	90	89
- Min.	85	95	80	70	70	50	83	81
HM Production (MT)								
- Max.	3.672	4.585	1.360	1.360	1.384	.845	12.361	11.822
- Min.	3.468	4.356	1.280	1.190	1.211	.650	11.345	10.784
1999-2000								
Installed Cap.(MT)	4.30	4.585	2.60	1.70	1.73	1.30	14.915	14.485
Cap.Utilisation factor(%)								
- Max.	95	100	85	80	95	65	93	90
- Min.	90	95	80	70	90	50	88	84
HM Production (MT)								
- Max.	4.085	4.585	2.210	1.360	1.643	.845	13.883	13.085
- Min.	3.870	4.356	2.080	1.190	1.557	.650	13.053	12.146

1.10 It can be seen that addition to capacity in RSP and Bhilai and modernisation schemes in the plants and renovation of IISCO will lead to improved capacity utilisation in all plants (ranging from 70 to 100%). The hot metal production is projected to increase to 11.8 MT in 1994-95 and 13.5 MT in 1999-2000 (Average between Min and Max.). This gives an annual compound growth rate of about 3%. However, as per SAIL Corporate Plan, the rate of growth in hot metal production is expected to be 6.5% per annum during the decade. It is significant to

note that the high rate of increase in production projected by SAIL is based more on an increase in the overall capacity utilisation factor (125% in 1999-2000 from 73.4 in 1989-90) rather than from in increase in the installed capacity (14.5 MT from the existing 13.26 MT). It is our feeling that while the increase in installed capacity will probably come about, the projected increase in utilisation factor is unlikely to materialize. We estimate the utilisation factor to marginally increase during this period in BSL, BSP and RSP and significantly increase in DSP and IISCO based on modernisation plans.

1.11 Mini Steel Sector

The production of steel from secondary producers may be grouped under two categories:

i) Re-rollers - who process semis and billets (and sometimes scrap plates) to various merchant sections in demand

ii) Electric Arc Furnace (EAF): which use pig-iron, sponge iron and heavy melting scrap for production of saleable steel.

Re-rollers do not add to the tonnage of steel output and so they are not considered. Essentially they process steel which has been produced by others.

Electric Arc Furnace (EAF)

Electric arc furnaces add to the total supply of crude steel in the country. Traditionally EAF industry has been set up with small furnaces (5-15 tonne capacity) to produce small quantities of special and alloy steels for specific users. Also the growth of the industry has been mainly dependent on purchase of heavy melting scrap (including imported scrap) and small quantities of purchased pig iron

and sponge iron. The advocates of EAF industry recommend the setting up of integrated facilities - direct reduction of iron ore into sponge iron, a large furnace (50 t or more capacity) for conversion of sponge iron into steel, continuous casting of the liquid steel into thin slabs or billets and the rolling of the steel into saleable sections. In the early stages of the industry, the units were of a minimum capacity of 50000 tpa with 2 x 10 t EAFs and continuous casting machines with scope for expansion. But, in the later years, a large number of uneconomic units with single EAF of 10 t and smaller capacity came into being and these could neither afford continuous casting or other improved technological features. Besides, this created a large excess capacity that exerted a backward pull on the larger and more efficient units.

Crude Steel Production from EAF

In 1975-76, the installed capacity of the mini-steel sector was about 2.85 mt/annum constituting 19.6% of the total installed crude steel capacity. The installed capacity at the end of 1988-89 is reported to be about 5.0 MT in 212 units. The production during the last three years is shown in Table 13.

Table 13 : Production of Crude Steel in EAF

Year	Total Steel Output (MT)	Output of EAF industry (MT)	EAF Share of the total (%)
1986-87	12.20	3.55	29.1
1987-88	13.10	3.25	24.8
1988-89	14.20	2.90	20.4

The production of crude steel from EAF sector has been declining mainly due to shortage of heavy melting scrap and power supply. The

EAF industry is dependent on import of heavy melting scrap which amounted to 1.5 MT in 1984-85, 2.16 MT in 1985-86 and 2.7 MT in 1986-87. Unless the sponge iron industry is developed and can meet the scrap requirements of the EAF industry, the development of the latter will be seriously affected.

Sponge-Iron

It is basically iron ore processed to make it useable in the electric arc furnace (EAF) for steel making. In simple terms, sponge iron is derived by reducing the oxygen in the ore through direct heating. Sponge iron is also known as directly reduced iron or DRI. The reductants or the fuel used for reductions either coal or gas.

In coal based plants, sponge iron is produced in a horizontal rotary kiln where the maximum capacity is 150,000 tonnes per annum. In gas plants, the capacity of a single module vertical shaft at the minimum is 440,000 tonnes while the upper limit may go up to 1 million tonnes. Gas based plants need larger investment but the investment per tonne of the final product is 30% lower because of higher capacity. Much of the production related problems of existing coal based sponge iron plants in India are attributed to inconsistent quality of coal and technological issues. Recently, the government has allowed the use of natural gas for sponge iron production. Natural gas is largely of consistent quality once it is de-sulpharised. Another advantage of gas based process is that the sponge iron can be hot-briquetted while the sponge-iron pellets are still hot. This is not possible in the coal based process because the ash has to be separated. In hot-briquetted iron, the reoxidation rate is much lower than in sponge iron and the integrated steel plants (TISCO) prefer it.

Present Status

India has a coal based DRI capacity of 0.33 Million Tonnes (in 3 units) in operation and 0.72 MT capacity under construction. In addition 1.41 MT capacity in 9 units are in the planning stage. Only one unit on gas based technology of capacity 0.88 MT is under construction at Hazira, in Gujarat. 3 more units based on natural gas are being planned. A list of existing and new manufacturers of sponge-iron is given in Annexure 1.2.

The production from coal based sponge iron plants which was 0.086 MT in 1984-85 has marginally increased to 0.14 MT in 1986-87. The capacity utilisation of these plants has been very low due to technology related problems and coal quality.

Modernisation of the Mini-steel Sector:

The mini-steel sector has a licensed capacity of about 6.5 MT but due to shortages of power and steel scrap the capacity utilisation has been low at about 50%. Moreover, a large number of units are not adequately equipped for the production of quality steel. If capacity utilisation is to be increased, adequate and uninterrupted supply of power and steel scrap is essential. Also technological updating of the promising units has to be carried out.

At present about 72% of the steel capacity is based on the conventional blast furnace route and 28% on the electric arc furnace route, which includes a small DR-EAF capacity. According to Dr.Dastur, in the Indian situation, the technological options are narrowed down because of the peculiar characteristics of Indian raw materials, fluxes and energy sources and their limited availability. These are as

follows:

a) high grade iron ore suitable for direct reduction is limited and that too localised in certain areas;

b) while adequate reserves of smelting grade iron ore are available, spread over several regions, some of these ores have to be agglomerated before use;

c) the availability of high grade pellets is limited;

d) the quantity and quality of Indian flux materials are not adequate for a modern expanding steel industry. Therefore, their imports will be necessary;

e) natural gas is available in certain areas. Most of these areas do not have adequate transport links and other infrastructure facilities. Also, the price of gas is comparatively very high for a gas-intensive process like DR; and

f) electric power availability is inadequate and in most of the regions uninterrupted supply from the public utility system is doubtful.

Availability from EAF Sector

The working group on iron and steel for the 8th plan has in its report projected the availability of steel from mini-steel plants at 4.50 MT in 1994-95 and 5.00 MT in 1999-2000. The availability from DRI-EAF units may increase from the present level of about 0.20 MT to about 1.50 MT assuming that all the units listed in Annexure 1.2 come into operation and operate at 60% capacity utilisation.

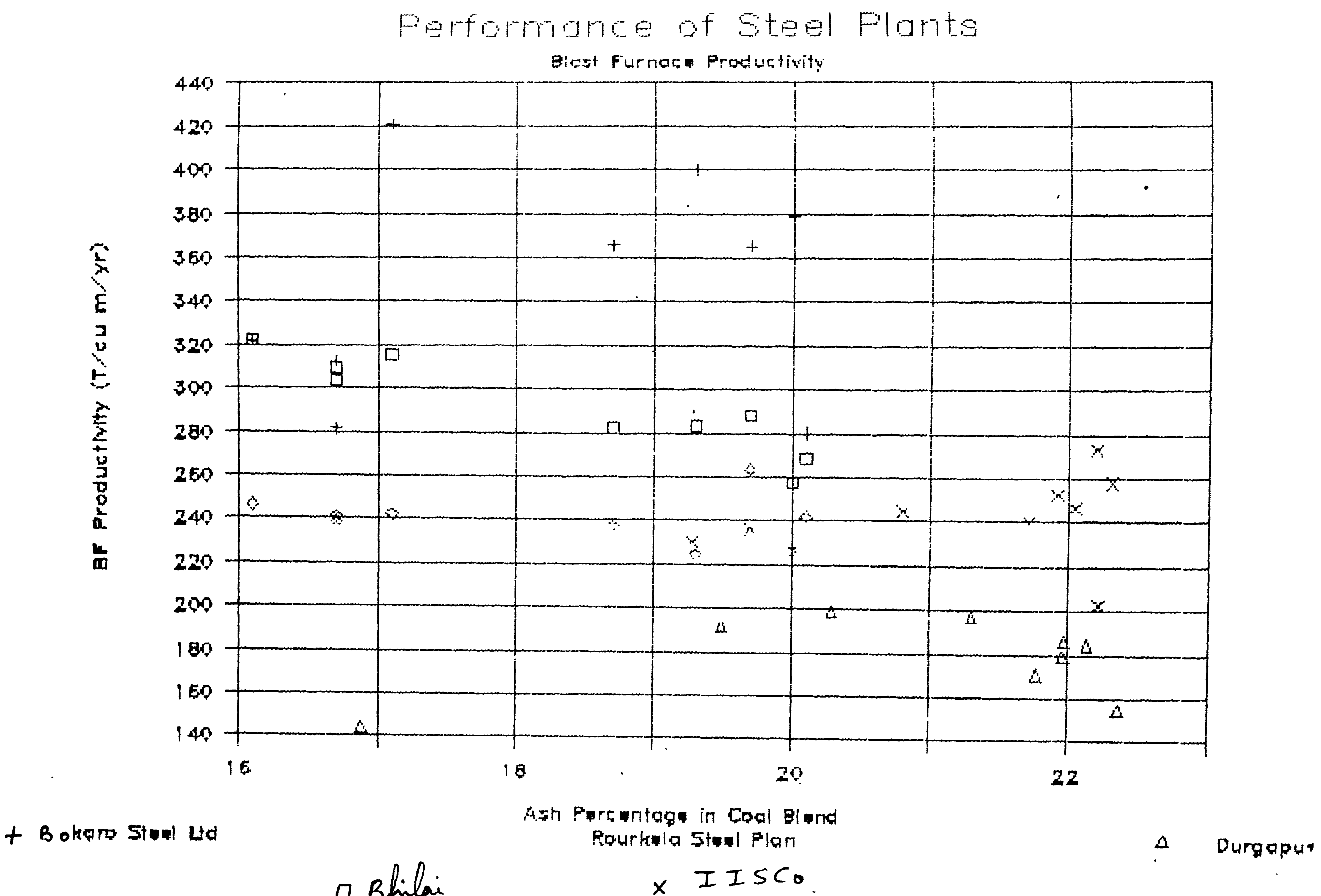


Fig.1: Blast Furnace Productivity vs Ash Percent in Coal Blend for the Steel Plants

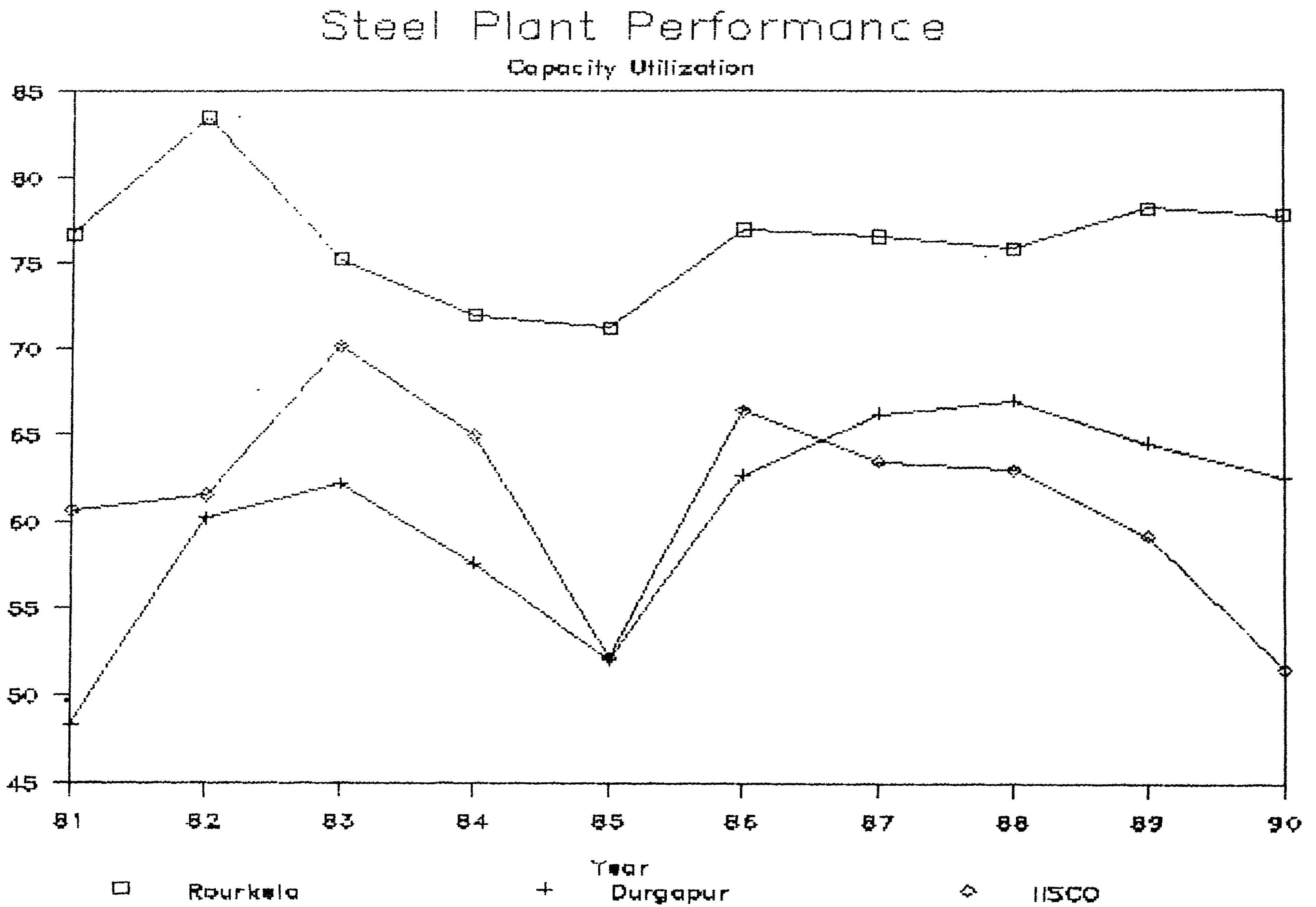


Fig.2: Capacity Utilization of RSP, DSP & IISCO

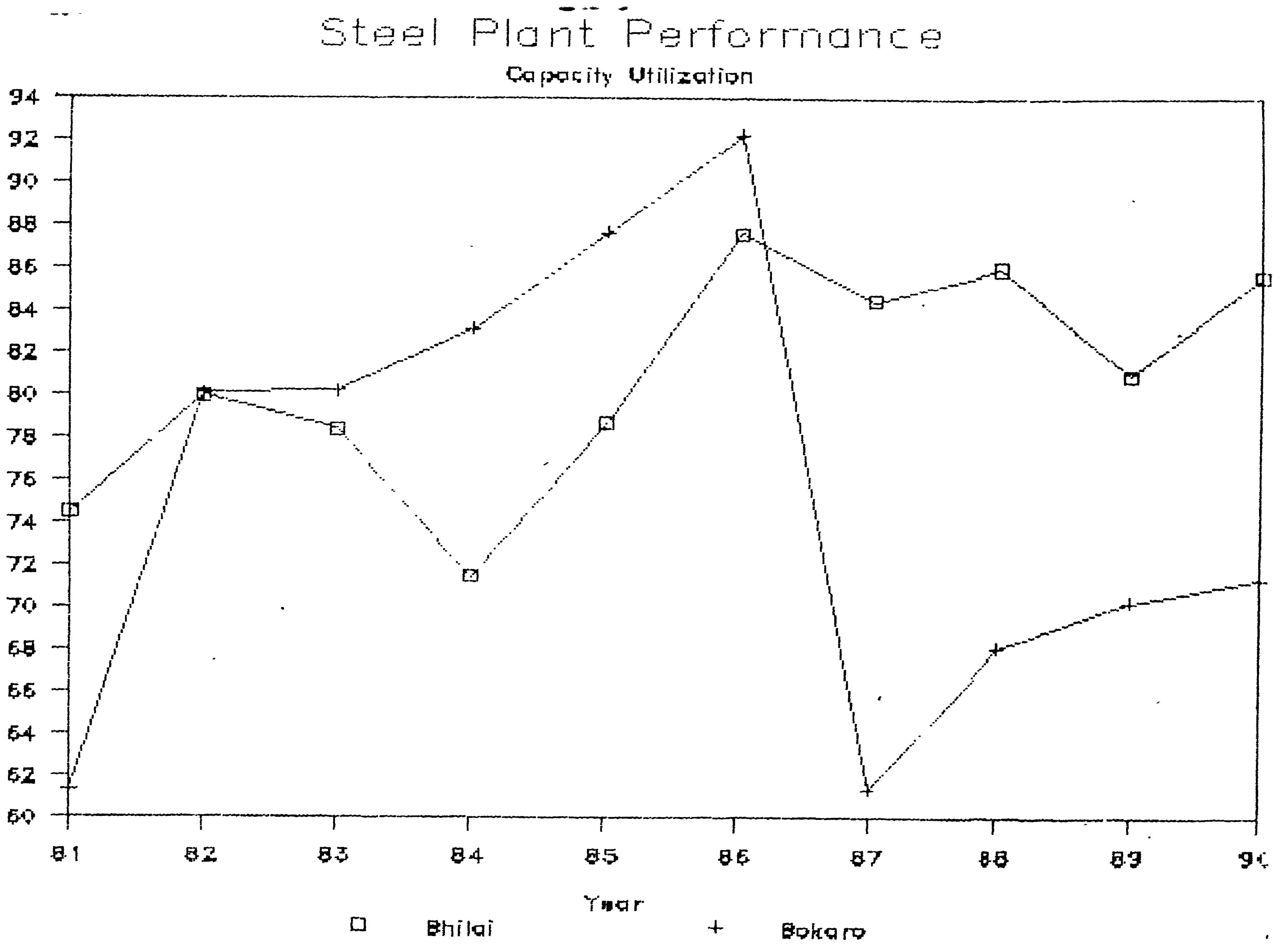


Fig.3: Capacity Utilization of BSP and BSL

CHAPTER 2
Coking Coal Quality and Demand Assessment

2.1 Introduction

The coking coal requirements for the blast furnaces, primarily depend upon the hot metal production programme of the steel industry, and the quality of coal. The requirement of coking coal is broken up into prime, medium and semi coking coals based on the projected coal blend ratios in the steel plants. The quality of coke is vital to the process of steel production. Good blast furnace operation demands supply of consistent and good quality coke low in ash content, properly sized and with appropriate strength characteristics. The quality of coke produced is primarily dictated by the quality of coal blend. The properties of coal blend generally considered desirable for manufacture of good quality coke in international steel plants are indicated in Table 14. Also a comparison of the quality of Indian coal blends with those of some efficient steel plants abroad is given in Table 15 below.

Table 14: Characteristics of Coal Blend Generally Preferred in International Steel Plants

Coal characteristics	Preferred Max	Acceptance Max
Ash content (%)	8	10
Volatile Matter (%)	26	30
Sulphur content (%)	0.6	1.0
Vitrinite content (%)	65	50
Vitrinite reflectance (%)	1.25	1.10
Crucible swelling no	7 min	5 min
Geisler Max fluidity	500 min	100 min

Source: "Report on Technology Evaluation Sources Study in Steel Sector (M N Dastur & Co. Ltd.)

Table 15: Comparison of Indian Coal Blends with those of some Efficient Steel Plants Abroad

Parameters		India	Abroad
Proximate Analysis, % (dry basis)			
Ash		18-22	6-10
Volatile matter		22-25	24-30
Coking properties			
Coking index (BS)		14-18	20-24
GK Coke type		F-G2	G3-G7
Free swelling index		2.5-4	5-8
Plastometric properties			
Maximum fluidity (Gieseler)	ddpm	50-300	500-700
Plastic layer thickness (Sopoznikov)	mm	17-21	22-26
Dilatometric indices			
Contraction	%	<20	25-30
Dilation	%	(-)ve	20-150
Petrographic properties			
Vitrinite	%	<55	<55
Reflectance of vitrinite (RO)	%	1.0-1.10	1.15-1.25

Source: IE (I) Journal-MM Vol.69, September, 1988

It can be seen that the coal blend used in our steel plants is significantly inferior in quality. A comparison of the qualities of coke produced in Indian steel plants and some efficient steel plants abroad are given in **Table 16**.

Table 16 : Coke Quality in India and Abroad

Parameters	India	Efficient Plants Abroad
Ash %	21-28	6-10
Moisture %	4-12	<4
Size, mm	25-100	25-80
Strength		
M10	10-17	<9
M40	75-80	>80
CR1	28-39	<30
CSR	24-45	>55

CRI = Coke reactivity Index; CSR = Coke strength after reaction
Source: IE(I) Journal - MM Vol. 69, September, 1988

It can be seen from the table that the quality of coke in Indian steel plants is inferior on many accounts. The quality of coke produced fluctuates widely due to variations in the quality of clean coal supplies. The trend in coke quality and blast furnace productivity for some SAIL steel plants from 1974-75 to 1985-86 is given in the Table 17 below:

Table 17: Coke Quality and Blast Furnace Productivity in Indian Steel Plants

Parameters	Unit	DPR Norms	74-75	76-77	78-79	80-81	82-83	84-85	85-86
BSP, Bhilai									
Ash in coal blend	%	17-18	18.09	18.99	20.20	20.10	18.70	19.3	-
Coke ash	%	23	25.15	25.60	26.80	26.60	24.70	25.30	23.30
M10 in coke	%	-	10.80	10.60	11.10	13.00	13.00	13.90	12.20
Productivity	t/m3/day	1.11/1.01	1.05	1.08	0.92	0.86	0.88	0.85	0.95
Coke rate	kg/thm	-	779	792	843	837	823	787	723
BSL, Bokaro									
Ash in coal blend	%	17	20.18	19.83	20.45	21.81	20.64	20.00	18.43
Coke ash	%	22.5	26.17	25.54	26.49	28.16	26.46	26.30	24.14
M10 in coke	%	8	8.82	9.90	10.00	12.90	13.20	12.20	12.40
Productivity	t/m3/day	1.32	1.07	1.21	0.87	0.80	0.80	0.91	0.83
Coke rate	kg/thm	720	752	700	693	777	752	709	728
RSP, Rourkela									
Ash in coal blend	%	17	18.68	18.91	18.95	19.41	18.52	20.00	18.28
Coke ash	%	24	25.01	27.35	26.79	26.53	24.15	25.82	23.8
M10 in coke	%	-	10.47	9.04	10.00	10.54	9.90	11.80	11.4
Productivity	t/m3/day	0.88/0.90	0.70	0.85	0.77	0.71	0.70	0.66	0.72
Coke rate	kg/thm	-	925	915	929	875	890	853	811

Source: IE(I) Journal - MM Vol. 69, September, 1988

2.2 Effect of Coke Quality on Blast Furnace Productivity

Quality of feed materials plays a vital role in influencing the performance of blast furnaces. The most important factor responsible for steady deterioration in the performance of Indian blast furnaces over the last few years has been the deteriorating quality of feed materials in general and coke quality in particular. Coke is the main source of heat and reducing gases in the blast furnace. Ash content,

reactivity, size and strength are the main quality parameters of coke that largely determine its behaviour in the blast furnace. Coke quality plays the most important role in determining the blast furnace performance as virtually all important aspects of furnace operation are directly influenced by coke. The blast furnace productivity is also appreciably reduced with increase in ash content in coke. The ability of coke to maintain the desired size grading during its descent in the furnace depends upon its strength. The degradation of coke due to inadequate initial strength or other factors raises the concentration of coke fines which also affects the productivity. The increase in ash content in coke also affects the quality of hot metal.

2.3 Effective Coal Blending for Improving Coke Quality

Narrow size range (25-80 mm), high resistance to abrasion (M10 < 9.0), high strength (M40 > 80), low coke reactivity index (CRI < 30) high coke strength after reaction (CSR >55), low ash (preferably below 15%) are some of the important features of coke required for good blast furnace operation at high productivity. This can be achieved by selection of superior coking coals in the blend, adequate homogenisation during blend preparation before coking, adoption of suitable pre-carbonisation technology and controls during and in post-coking stages.

The run-off mine coking coals in India contain over 28% ash. The ash content of washed coal generally varies between 18 to 22%. Each steel plant under SAIL gets its coking coal supplies from 8-10 sources and therefore, it is essential to provide coal blending facilities in all steel plants so that consistency of blend quality could be improved. These have been provided in the modernisation plans of SAIL

plants. Also the supply of coal from different sources needs to be regulated so that blending facilities are effectively utilised. In order to predetermine the appropriate blend characteristics, experimental coke ovens are used for carrying out systematic tests at Central Fuel Research Institute (CFRI) Dhanbad, RDCIS (Ranchi) and TISCO (Jamshedpur). The coking property of Indian coal blends is inferior in all parameters. The coking index (CI) generally lies within 14-18, GK coke type is in the range of F-G_2 and Free Swelling Index (FSI) varies within $2^1/_2$ to 4. The maximum fluidity level ranges from 50-300 ddpm (dial divisions per minute) in Gieseler test and Plastic layer thickness (PLT) of 17-21 mm in Sopozhnikou test. Most of these coals have low vitrinite content (< 55%) and low rank (RO < 1.1). For good coking coal, the coal blend should achieve a fluidity level of 200-1000 ddpm and PLT of over 22mm. This is the reason for the import of low ash high grade coking coal by SAIL constituting 10-25% in the coal blend used in different plants.

2.4 Coking Coal Demand Assessment

The first detailed analysis for assessing the requirements of coal for the steel industry was carried out in 1956 by the Energy Survey Committee. Subsequently, the Fuel Policy Committee (1973) estimated the coking coal requirement for the steel industry and foundries taking into account the hot metal production targets, coke rates, sized coke requirements, losses in coke making, dry coal requirements, raw and washed coal feeds etc. The total raw coal required was derived taking all salient parameters. The working group on energy policy (1979) on the other hand, made a broad estimate adopting a uniform norm of coking coal to hot metal ratio of 2.88. In the 6th Plan

document, while estimating the coking coal demand during the 6th Plan period, the following observations were made in the technical note:

i) Because of high ash content of Indian coals, most of the coking coals are washed and blended and dry coal is converted to sized coke for use in blast furnace;

ii) because of variation in quality of mined coal, consumption norms cannot be built up from ratios of hot metal output to raw coal input;

iii) norms based on dry coal are also showing less reliability in demand forecasting because of the variation of ratios of sized coke to dry coal because of quality of coal;

iv) to estimate raw coal to be mined to meet the coke demand, ratios of blending of various grades of coal, recoveries in washeries, losses due to handling, moisture and transport have to be taken into account;

v) share of imported coal in the blend is to be carefully assessed.

2.5 Demand Projection for 7th Plan

In September 1984, the government set up another committee (Jha Committee) to make detailed evaluation of coking coal requirements for the iron and steel sector for the 7th Plan. The Commitee's assessment was reflected in the working group's report for the 7th plan. An important aspect of the study related to the demand-supply balance of prime coking coal taking into account the revised raw coal linkages to washeries after delinking coal jointly accepted by steel and coal

sectors as unsuitable. The following blend ratios were adopted for assessing the demand of coking coal in the 7th Plan.

Table 18: Coal Blend Ratios Adopted for 7th Plan

Category	BSP	RSP	DSP	BSL	IISCO	TISCO	VSP (Projected	AV.
Prime	58	50	70	50	65	60	55	58
Medium	35	40	20	50	25	30	45	35
Blendable	7	10	10	-	10	10	-	7

The blend ratio indicated above was more or less in line with actual consumption pattern during the 6th plan period. The committee also looked into the operable capacity of washeries in working out the raw coal linkages and washed coal output. The demand estimates made by the Jha committee for all steel plants together are given in the **Table 19** below.

Table 19: Coking Coal Demand for the Steel Sector (7th Plan)

Million Tonnes

Item	1985-86	1986-87	1987-88	1988-89	1989-90
Hot metal	10.68	11.63	12.74	13.80	14.71
Overall coal demand (Dry)	17.92	19.70	21.28	22.91	23.92

2.6 Demand Projections for the 8th Plan

2.6.1 The government of India has constituted Working Groups for assessing the demand for steel, hot metal production and coking coal requirements for the 8th Plan period. The SAIL's "Corporate Plan upto 2000 AD" (May 1987) gives the hot metal production programme, coking coal requirements and coal:hot metal ratio. This has been subsequently revised by SAIL. VSP and TISCO have also finalised the hot metal production plan and other input requirements. A summary of the hot

metal production plan and coal requirements as per the Working Groups Report is given in the Table 20 below:

Table 20 : Hot Metal Production Plan and Coal Requirement

Steel Plants	1990-91	1991-92	1992-93	1993-94	1994-95	1999-2000
1. SAIL						
Hot Metal Production(MT)	11.95	12.13	12.53	13.46	15.06	18.15
Coal: Hot Metal Ratio	1.29	1.25	1.24	1.23	1.18	1.03
Coal Requirement (MT)	15.37	15.21	15.55	16.49	17.71	18.70
2. VSP						
Hot Metal Production(MT)	1.40	2.55	3.40	3.40	3.40	3.40
Coal: Hot Metal Ratio	1.31	1.31	1.19	1.19	1.19	1.19
Coal Requirement (MT)	1.83	3.34	4.05	4.05	4.05	4.05
3. TISCO						
Hot Metal Production(MT)	2.30	2.55	2.60	2.60	2.60	2.60
Coal: Hot Metal Ratio	1.13	1.08	1.08	1.08	1.08	1.08
Coal Requirement (MT)	2.60	2.75	2.81	2.81	2.81	2.81
4. Total						
Hot Metal (MT)	15.65	17.23	18.53	19.46	21.06	24.25
Coal Requirement (MT)	19.80	21.31	22.35	23.35	24.56	25.56

Note: Based on the report of the Working Group for Coal and Lignite (8th Plan)

The plantwise details for SAIL and VSP are given in **Annexure 2.1**. The annexure also indicates the percentage of different categories of coal in the blend based on which the requirement of prime, medium and semi and imported coals have been derived. A summary of the categorywise coal requirement for SAIL and VSP based on their demand projections is given in the **Table 21** below:

Table 21: Categorywise Coal Demand for SAIL and VSP (MT)

Items		1994-95	1999-2000
Coal Requirement			
i)	Prime	7.76	6.75
ii)	Medium	8.50	8.89
iii)	Semi	1.01	1.06
iv)	Imported	4.46	6.03
	Total	21.73	22.73

Note: Based on the report of the Working Group for Coal & Lignite

2.7 Demand Projection Based on Realistic Assessment of Hot Metal Production

2.7.1 The hot metal production for 1994-95 and 1999-2000 has already been worked out based on achievable capacity utilisation of blast furnace and is given in Table 13. The tables 7 to 11 also indicate the ash percent in coal blend and the coke rate for each steel plant during the period 1989-90. It is observed from the tables that the coke rate has been going down gradually with reduction in ash percent. An average ash content in the coal blend of 17% or less has been achieved in BSP, BSL and RSP during the last 3 years. This has been possible partly due to increasing share of imported coal in the blend and partly due to improvement in quality of indigenous supplies. Moreover, as projected by coal industry, the indigenous supplies will have an ash content of 17% from 1992-93 onwards.

2.7.2 Coke Rate for 1994-95 and 1999-2000

For 1994-95 the coke rate is assumed at or near the same level as achieved in 1989-90 for BSP, BSL and RSP. For DSP and IISCO, some improvement in coke rate is assumed. For 1999-2000, two scenarios are considered for coke rate:

1) coke rate as projected by SAIL plan assuming 15% ash in coal blend; and

2) coke rate which is the average of 1989-90 and the 1999-2000 figure

The hot metal production and coal requirements have been worked out for SAIL steel plants under two conditions: a) with IISCO renovation plan and b) without IISCO renovation plan. The plantwise details are given in **Annexure 2.2**. The summary is given in the Table 22.

Table 22 : Hot Metal Production Plan and Coal Requirement for SAIL Plants (realistic assessment)

Items	1989-90	1994-95 Max	1994-95 Min	1999-2000 Max (2)	1999-2000 Min (2)	1999-2000 Max (1)	1999-2000 Min (1)
1. With IISCO renovation							
a) Hot Metal Prod.(MT)		12.336	11.479	14.10	13.27	14.10	13.27
b) Av.Coke Rate T/THM		0.71		0.67		0.63	
c) Av.Coal:Hot metal		1.15		1.09		1.03	
d) Coal requirement(MT)		14.19	13.22	15.33	14.42	14.48	13.63
2. Without IISCO renovation							
a) Hot Metal Prod.(MT)	9.736	11.797	10.918	13.302	12.363	13.302	12.363
b) Av.Coke Rate T/THM	0.74	0.72		0.68		0.64	
c) Av.Coal:Hot metal	1.21	1.17		1.03		1.03	
d) Coal requirement(MT)	11.77	13.78	12.73	14.48	13.60	13.76	12.72

2.7.3 Categorywise Coal Demand for SAIL Steel Plants

To arrive at the categorywise coal demand for the steel plants in 1994-95 and 1999-2000, the distribution projection as per SAIL's Corporate Plan for 1994-95 has been taken. This more or less agrees with the present share of imported coal in the steel plants. The average of the maximum and minimum coal requirements as worked out earlier for the two time horizons is taken for assessing categorywise coal demand. A summary of the categorywise coal demand for SAIL and VSP is given in Table 23. The plantwise details are given in Annexure 2.3.

Table 23: **Categorywise Coal Demand for SAIL and VSP (MT)**

Category	1994-95	1999-2000 Scenario 1	1999-2000 Scenario 2
1. SAIL (with IISCO renovations)	13.71	14.88	14.06
i) Prime	4.78	5.19	4.93
ii) Medium	5.29	5.72	5.41
iii) Semi	0.77	0.84	0.79
iv) Imported	2.87	3.11	2.93
2. SAIL (without IISCO renovations)	12.81	13.59	12.79
i) Prime	4.33	4.55	4.29
ii) Medium	5.02	5.34	5.03
iii) Semi	0.68	0.72	0.67
iv) Imported	2.78	2.98	2.80
3. VSP	4.03	4.03	4.03
i) Prime	1.41	1.41	1.41
ii) Medium	1.81	1.81	1.81
iii) Semi	-	-	-
iv) Imported	0.81	0.81	0.81

Note: For SAIL, the categorywise distribution is based on SAIL Plan for 1994-95. For VSP it is based on Working Groups Report.

2.8 Analysis of Coal Utilisation in Blast Furnaces

The principal use of metallurgical-grade coal world-wide is for the production of blast furnace coke. In India, this grade of coal, like all other coals, has a comparatively high ash content, as well as poor strength and low reactivity. As a result, these coals are unable to provide high-quality coke capable of producing high-grade steel, and consequently blend of these coals with imported coking coal becomes necessary. In spite of this blending, coke rate at SAIL steel plants varies between 650 to 800 kg/THM compared to the international norm of 400 to 500 kg/THM. Similarly, coke strength, as measured by the M-10 index, varies between 11 and 13 whereas the world standard is between 5.5 and 8.

In this perspective, the relationship between coal blends and coke properties (M10 and M40) have been analyzed here so as to arrive at optimum blends that maximize M40 and minimize M10. For this purpose, 3-year monthly data for three SAIL plants (Bhilai, Bokaro, and Rourkela) with respect to their blast furnace productivity, coke-rate, coke properties (ash percentage, M10 and M40) and coal blend composition (overall ash content, and percentages of imported coal, indigenous prime, medium and blendable coals) was obtained from SAIL.

In a statistical sense, this data is of limited value since extrapolations of trends and correlations cannot be made due to the rather narrow ranges of all the variables. This latter reason lead to poor co-relationship between coke rate and coal blend composition, though certain qualitative features did emerge. These are:

(a) The coke rate increases sharply when the coal blend ash content is greater than 18.5%.

(b) The coke rate seems rather insensitive to medium-plus-blendable coal fractions as high as 50 per cent. The major parameter governing coke rate seems to be the ratio of the imported coal fraction to indigenous prime coking coal fraction in the blend.

2.9 Optimal Coal Blend for BSP, RSP and BSL

In order to quantify the optimal coal blends for each of the three steel plants with respect to coke properties, the coke strength, M10, was correlated to the various constituents in the blend using the Merrick model:

$$(100/M10) = AP^2 + BM^2 + CI^2 + 2DMP + 2EPI + 2FMI \qquad \ldots(1)$$

where P, M, and I are the percentages of indigenous prime coking coal, indigenous medium-plus-blendable coking coal, and imported coal, respectively, in the blend. A, B, C, D, E, and F are constants which are determined by regression. Linear regression of the data for the three steel plants to the form of equation (1) was carried out. Table 24 lists the values of each of the six constants for all the three plants.

Table 24: Regression Constants for the Merrick Model

Steel Plant	Constants					
	A	B	C	D	E	F
Bhilai	-0.95892	-0.61401	-0.05531	0.77643	0.36357	0.28875
Bokaro	0.01615	0.03190	0.34231	0.00066	-0.02371	-0.07238
Rourkela	-2.5906	-1.54564	-0.00231	2.01039	-0.16349	0.54831

The plant data is compared with the correlated form of equation (1) in Figure 1 to show goodness-of-fit. The diagonal line in Figures 1(a), 1(b), and 1(c) represents exact fit of plant data and predictions due to correlations.

Next, to determine the blend composition which minimizes M10, equation (1) was partially differentiated with respect to each of these variables (P, I, and M) and the three equations set equal to zero. Consequently, if P^*, I^*, and M^* represent the optimal percentages of P, I, and M in the blend with the lowest M10 values, then:

$$AP^* + DM^* + EI^* = 0 \quad \text{...(2)}$$

$$DP^* + BM^* + FI^* = 0 \quad \text{...(3)}$$

$$EP^* + FM^* + CI^* = 0 \quad \text{...(4)}$$

Substituting the values of the constants (A through F) for each of the three plants from Table I, the eigenvectors and eigenvalues for the system of equations (2), (3) and (4) were obtained. The optimal percentages of blend composition for the three plants are listed in Table 25. The M10 values corresponding to these compositions are between 8 and 9.5.

Table 25 : Blend Composition that Minimizes M10 Index

Steel Plant	Percentage of Blend		
	Indigenous Prime	Indigenous Medium + Blendable	Imported
Bhilai	25	35	40
Bokaro	30	50	20
Rourkela	28	40	32

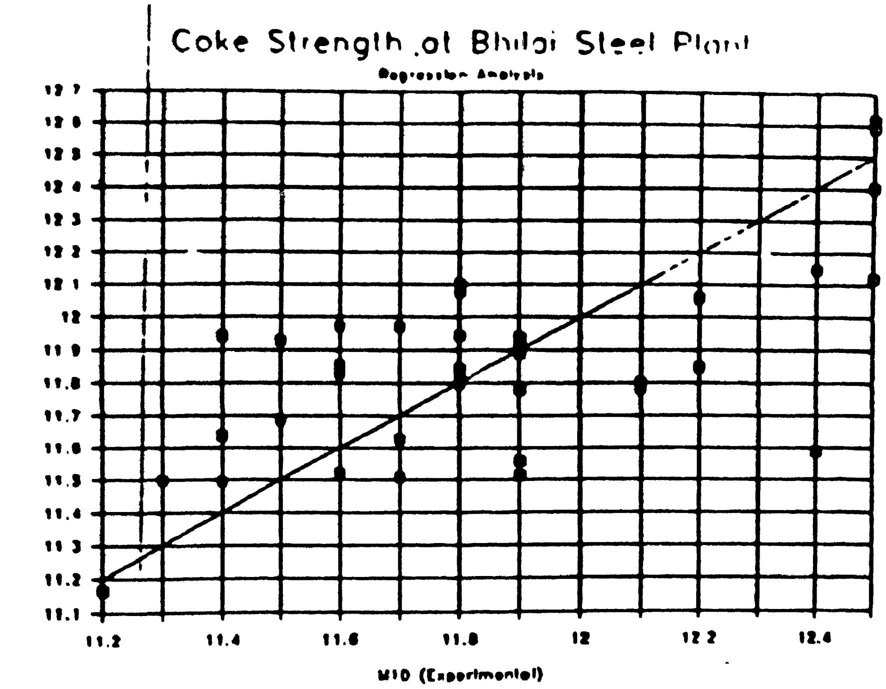
2.10 Coal Demand Assessment Based on Optimal Blend for SAIL Plants

Based on the above optimal percentages of blend composition for BSP, RSP and BSL and the blend composition projected for DSP and IISCO (as per SAIL), the total categorywise coking coal requirement has been worked out keeping the hot metal production and the coal-hot metal ratio at the same level as in Table 22. A summary of the categorywise coal requirement is given in the table below. The plantwise details are given in Annexure 2.4.

Table 26: Categorywise Coal Demand for SAIL Plants (MT)

Steel Plant	1994-95	1999-2000 Scenario-1	1999-2000 Scenario-2
1.With IISCO renovation	13.71	14.86	14.06
i) Prime	4.41	4.79	4.53
ii) Medium	4.91	5.31	5.00
iii) Semi	0.77	0.84	0.81
iv) Imported	3.62	3.94	3.72
2.Without IISCO renovation	12.81	13.59	12.79
i) Prime	3.96	4.15	3.89
ii) Medium	4.65	4.92	4.63
iii) Semi	0.67	0.71	0.68
iv) Imported	3.53	3.81	3.59

Note: Categorywise distribution is based on optimal blend derived for BSP, BSL and RSP. For DSP and IISCO, it is based on SAIL Plan for 1994-95.


Coke Strength at Bhilai Steel Plant
Regression Analysis
M10 (Predicted)
M10 (Experimental)

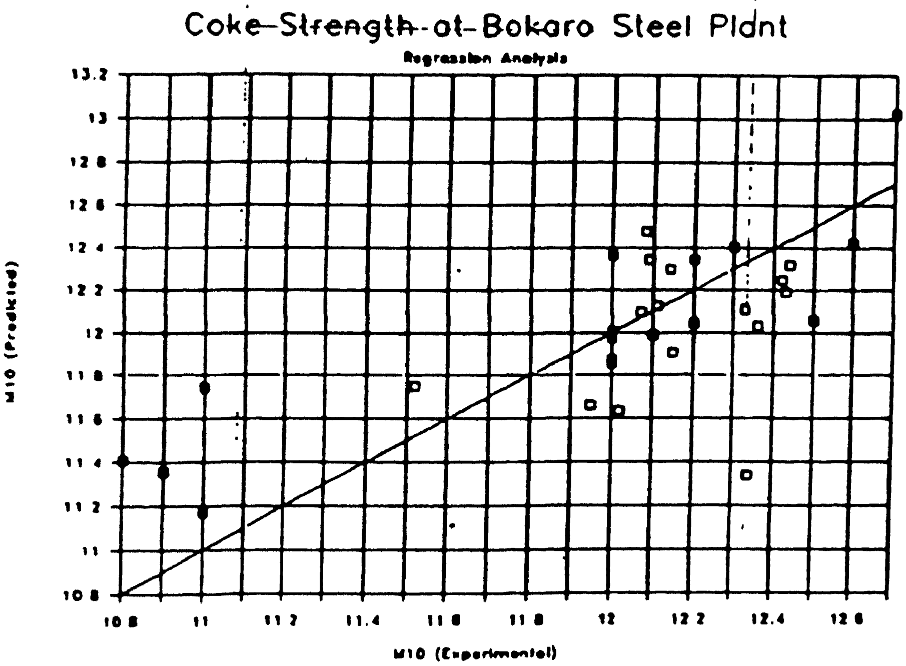

Coke Strength at Bokaro Steel Plant
Regression Analysis
M10 (Predicted)
M10 (Experimental)

FIG 1(b)

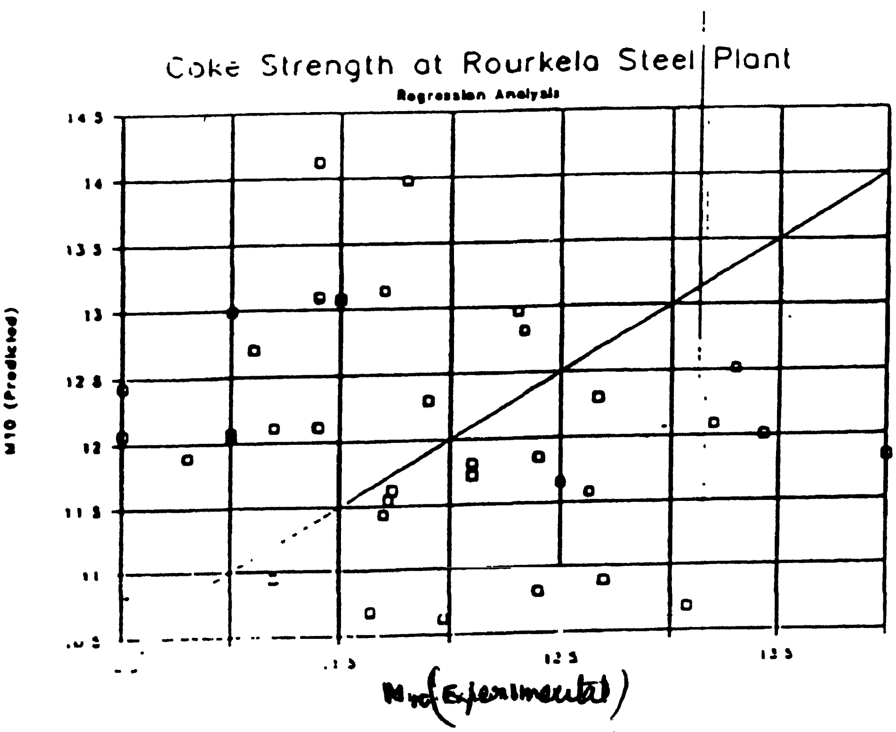

Coke Strength at Rourkela Steel Plant
Regression Analysis
M10 (Predicted)
M10 (Experimental)

FIG 1(c)

CHAPTER 3
Availability of Coking Coal for Steel Plants

3.1 Prime Coking Coal Reserves

The only source of prime coking coal in the country is Jharia coalfield in Bihar. The reserves position (as on 1.1.89) is given in the Table 27 below:

Table 27: Prime Coking Coal Reserves
(million tonnes)

Depth (metres)	Proved	Indicated	Inferred	Total
0-600	3659.0	380.0	-	4039.0
600->200	512.0	749.0	-	1261.0
Total	4171.0	1129.0		5300.0

Source: Department of Coal and CMPDI

Out of these reserves, it is proposed to work 1018 million tonnes (within 600 metres depth) by opencast mining method and the balance 4282 million tonnes by underground method. 9 opencast projects have been formulated for optimum exploitation of prime coking reserves from depths within 600 metres. However, it is estimated that 797 million tonnes of prime coking coal are locked up under fire and other surface structures in opencast mines and 1030 million tonnes are estimated to be locked up under surface structure in underground mines.

3.2 Medium and Semi Coking Coal Reserves

Medium and semi coking coal reserves are available in Jharia, Raniganj, East Bokaro, West Bokaro, Ramgarh and North Karanpura coalfields. Sizeable coking coal reserves of relatively lower rank have been found in Jhilmilli, Sonhat and Pench Kanhan valley

coalfields. Deposits of good quality coking coal with strong coking propensity has been located in the Northern part of Sohagpur coalfield. The high sulphur tertiary coals of upper Assam coalfields also show high coking characteristics. Details of the coalfield wise reserves are given in **Annexure 3.1**. A summary of medium and semi coking coal reserves is given in the **Table 28** below:

Table 28: Medium and Semi Coking Coal Reserves

(Million tonnes)

Depth (metres)	Proved	Indicated	Inferred	Total
Medium coking				
0-600	11433.6	7720.4	868.6	20027.6
600-1200	2420.0	1859.0	247.0	2348.0
Total	11780.6	9579.4	1115.6	22375.6
Semi-coking				
0-600	167.8	539.0	106.9	813.7
600-1200	27.0	256.0	506.0	789.0
Total	194.8	795.0	612.9	23978.3

Source: CMPDI

3.3 Quality of Coal Required by Steel Plants

Iron making through the route of blast furnace is greatly influenced by the quality of coke such as its strength (M10 index), fixed carbon, ash content etc. Coke making, therefore, assumes a great significance in relation to iron making and is particularly so in the context of deteriorating quality of coking coal as it affects the operational efficiency at the plant level. It is also causing great concern at the national level for obtaining good quality coking coal from the coal mines. As quality of coke from coke ovens will be greatly affected by the quality of the blend of different coking coals charged to the oven batteries it is considered important to observe the acceptable quality of coking coal as laid down by CFRI and adopted by the Steel Plants. The details are given in **Table 29**.

Table 29: SAIL'S Quality Parameters as Laid Down by CFRI

Parameters	Prime Coking	Medium Coking Medium Volatile	Medium Coking Low Volatile	Semi Coking
Ash %	17 + 0.5	17 + 0.5	18 + 0.5	16 + 0.5
Volatile Matter % (Dmmf)	22 - 32	32 - 37	20 - 22	33 - 44
Moisture %	1 - 2	1 - 2	Less than 1	2 - 4
Free Swelling index	More than 3	Around 3	Around 2	Around 3
Caking index	20/22	18	18	14
Coke type	G and above	E - G	E - G	EF but not below C/D
Reflectance	1 - 1.4	0.85 - 0.95	1.45 - 1.55	0.75 - 0.85
Carbon	88 - 91	86 - 90	90 - 91.5	83 - 85

3.4 Beneficiation of Coking Coal

The major proportion of coking coal reserves are high in ash content and before being supplied to steel plants their ash content is required to be reduced to acceptable limits by suitable beneficiation. There are 19 operating washeries with a raw coal input capacity of 35.50 MT. Of these 10 are prime coking coal washeries with an installed capacity of 18.50 MT and 9 are medium coking coal washeries with an installed capacity of 17.00 MT. The list of existing washeries with other details are given in **Annexure 3.2**. The operable capacities of these washeries have been assessed and are also given. Three washeries are under construction, 2 in prime coking coal and 1 in medium coking coal sector. These are Madhuband (capacity, 2.50 MT/a), Putki (3.0 MT/a) and Kedla (2.60 MT/a). All these are likely to be commissioned between 1991-92 and 1993-94.

3.5 Limitations of Existing Coal Washeries

The existing washeries were designed to beneficiate relatively easy or moderately difficult to wash coking coal, based on original linkages to the washeries. The linkages have undergone a change resulting in changes in the characteristics of coal like ash content and washability characteristics. Seamwise distribution of ROM coals fed to washeries have deteriorated and production from lower coal seams with inferior coking properties have increased as compared to production from upper coal seams in Jharia coalfield. This has resulted in increased ash content in raw coal feed and other operational problems in washing circuits. Also many of the existing washeries have serious design/equipment deficiencies in handling and blending of raw coal, screening, crushing, washing equipment etc. The inherent 'difficult to wash' characteristics of Indian coals, presence of higher proportion of near gravity materials (NGM), lower seam mining of coal, increased mechanisation of mine, change in seamwise composition of raw coal linked to washeries, lack of suitable coal slurry upgradation facilities etc. have been responsible for the continuous deterioration in the performance of coal washeries (especially prime coking) affecting the quality of washed coal supplies.

All these issues were examined in detail recently by two committees constituted by the government. One committee was headed by Shri P.R.Sinha, CMD, BCCL and the other committee was headed by Dr.V.A.Altekar, Ex Director, National Metallurgical Laboratory.

3.6 Recommendations of the Two Committees:

The major recommendations of the committees are as under:

i) Provide deshaling plant in the washeries so as to reduce shaly material before the coal is further processed for beneficiation. Such deshalers are to be introduced in Bhojudih, Sudamdih, Dugda I & II and Kargali washeries;

ii) Provide fine coal beneficiation at Bhojudih, Datherdih and Kargali washeries;

iii) Resort to finer crushing of ROM coal so to liberate impurities and improve yield of clean coal. This is to be done in Dugda I, Patherdih, Bhojudih and Sudamdih washeries;

iv) Provide instrumentation/automation system, ash monitors, computerisation of maintenance system etc. in all washeries;

Based on these recommendations, modification schemes have been prepared for each washery and these are under implementation.

3.7 Availability of Prime, Medium and Semi Coking Coals

The new washeries under construction are being provided with latest technologies for benficiation along with micro processor based logic controller etc. to ensure consistency and improvement in the quality of washed coal. When modifications of the washeries would be completed, the objective of maintaining overall ash level of 17 +/- 0.5% in the indigenous coal supplies is likely to be achieved. The modification programme includes short term and long term measures. The average ash content of indigenous coking coal supplies is expected to be about 18.5% in the first two years of the 8th Plan. From 1992-93 onwards, when the modification schemes are fully implemented, average

ash level in the clean coal supplies will be maintained at 17.5%. Table 30 shows the total availability of prime, medium and semi coking coal from indigenous sources with their expected weighted average ash content in the supplies. The washerywise projected availability of coking coals for the period from 1990-91 to 1999-2000 are given in the **Annexure 3.3 and 3.4.**

Table 30: Availability of Coking Coal for SAIL and Vishakapatnam Steel Plant

(Million Tonnes)

Category	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1999-2000
Prime (MT)	6.00	6.51	7.10	7.67	8.53	9.22	9.45
Wt.Av. Ash%	19.0	18.5	18.5	17.5	17.0	17.0	17.0
Medium (MT)	5.14	5.35	5.63	5.76	6.47	6.68	6.90
Wt.AV. Ash%	18.5	18.0	17.5	17.0	17.0	17.0	17.0
Semi (MT)	0.66	0.66	0.72	0.80	0.89	1.01	1.07
Total	11.80	12.52	13.45	14.23	15.89	16.91	17.42

Source: CMPDI

3.8 Demand-supply Balance of Coking Coal:

A balance sheet on the coal demand-supply for different scenarios as detailed below is prepared based on the demand and supply assessment already carried out for SAIL and VSP plants.

Scenario 1

Coal demand is based on SAIL and VSP plans for hot metal production. The categorywise distribution is based on blend proportion for the different steel plants as per the SAIL Plan and the report of the Working Group on Coal and Lignite for VSP (See **Annexure 3.5/1**).

Scenario 2

Coal demand is based on a realistic assessment of hot metal production plan of SAIL. The categorywise distribution is based on blend proportion figures projected for the different steel plants in 1994-95 as per SAIL plan and the same is assumed for 1999-2000. For VSP it is based on Working Group's Report (Annexure 3.5/2).

Scenario 3

Coal demand is based on a realistic assessment of the hot metal production plan of SAIL. The categorywise distribution is based on optimal blends (derived in para 2.9) for BSP, RSP and BSL and projected blends for DSP and IISCO (as per SAIL) and VSP (as per Working Group) (Annexure 3.5/3).

The summarised results of the total imported coal requirement on quality consideration for Scenario 1, 2 and 3 and the demand-supply balance of indigenous, prime, medium and semi-coking coals are given in Table 31. The details are given in Annexure 3.5. The balance sheets have been drawn based on wet coal demand at the steel plants.

Table 31: Summary of Coal Demand - Supply Balance for SAIL & VSP

(Million Tonnes)

Item	1994-95 (a)	(b)	1999 - 2000 2(a)	2(b)	I(a)	2(b)
1. Imported Coal Requirement						
a) Scenario - 1	5.50	-	-	-	6.22 -	-
b) Scenario - 2	3.68	3.59	3.92	3.72	3.74	3.61
c) Scenario - 3	4.43	4.34	4.75	4.62	4.53	4.40
2. Surplus/deficit of indigenous coal						
a) Scenario - 1						
Prime	0.98	-			2.27	-
Medium	(-)2.37	-			(-)2.48	-
Semi	(-)0.06 -	-			(-)0.06	-
Total	(-)1.45	-			(-)0.27	-
b) Scenario - 2						
Prime	2.64	3.11	2.43	3.09	2.71	3.39
Medium	(-) 0.87	(-) 0.59	(-) 1.03	(-) 0.78	(-) 0.70	(-) 0.30
Semi	0.20	0.29	0.18	0.31	0.23	0.36
Total	1.97	2.81	1.58	2.62	2.22	3.45
c) Scenario - 3						
Prime	3.03	3.51	2.85	3.54	3.13	3.81
Medium	(-) 0.47	(-) 0.19	(-) 0.59	(-) 0.18	(-) 0.26	(-) 0.13
Semi	0.19	0.30	0.18	0.31	0.21	0.35
Total	2.75	3.62	2.44	3.67	3.08	4.29

Note:

i) Imported coal requirement is based on quality considerations and for scenario-1 also includes deficit in indigenous supplies;

ii) Column (a) denotes situation after IISCO renovation and column (b) denotes IISCO without renovation;

iii) For 1999-2000, two situations are considered which reflect different coke rates for SAIL
1 - coke rate as per SAIL Plan and 2 - Average of coke rate in 1989-90 and 1999-2000.

CHAPTER 4
Economic Costing of Coking Coal Supplies to Steel Plants

4.1 Economic Costing

Economic costs have been chosen for comparison since they reflect the real cost to the economy by excluding transfer payments (duties and taxes) from the capital costs. Cost of imported coal has been increased by 25% in economic costing in order to incorporate its scarcity. (This is the permitted value by the Ministry of Finance). The capital costs and operating costs of the different projects have been taken from project reports. All costs have been updated to January 1989 based on different cost indices.

For prime coking coal, Putki-Baliari mine (an underground mine) and Putki washery and Block-II opencast mine and Madhuband washery have been considered. These are new units under construction in the prime coking coal sector. For medium coking coal, Rajrappa mine, Rajrappa washery and Kedla Washery have been considered. Rajrappa mine and washery are new units and construction has been completed. Kedla washery is under construction and is representative of future medium coking coal washery. Kedla washery will receive coal from 2-3 opencast mines in the area. For arriving at the cost of clean coal from Kedla washery for comparison purposes the combination of Rajrappa mine and Kedla washery is taken. Rajrappa mine is typical of an opencast mine in the area. It is assumed that coking coal is imported from Australia at Vishakapatnam port and a new coal unloading arrangement at Vishakapatnam Outer Harbour will be considered. Economic costing has been carried out for these five sources of supplies as given in Table 32.

Table 32: Economic Costing of Coking Coal Supplies

	Mine & Washery	Raw Coal output/annum	Clean Coal output/annum (Million Tonnes)
1.	Putki-baliari mine + washery	1.66	0.83
2.	Block II Oc Mine + Madhuband Washery	2.50	1.19
3.	Rajrappa mine + Rajrappa washery	2.60	1.37
4.	Typical opencast mine + Kedla washery	2.60	1.20
5.	Imported coal unloading arrangement at Vishakapatnam port	3.50	-

For serial nos. 1, 2 and 4 the financial and economic costs have been computed for both 100% and 85% capacity utilisation of the projects. For serial no. 3 the costs have been computed for 85% capacity utilisation of the washery.

4.2 Putki-Baliari underground mine (Prime coking coal) : capacity 1.6 MT/tonne

The cost figures are based on the capital costs given in the revised project report for Putki-Baliari mine, prepared by the British Mining Consultants Ltd., United Kingdom in December 1988. The costs have been updated to January 1989 using the following indices:

	Item	Dec. 1988	Jan. 1989
i)	Wholesale Price Index	434.4	438.1
ii)	Machinery index	387.6	395.2
iii)	Vehicles index	493.8	493.9
iv)	Consumer price index	161.0	165.0

The financial operating costs has been computed from the fixed and variable costs given in the report. The economic capital cost is used while computing the economic operating cost. **Annexure 4.1** shows the phasing of capital expenditure for the mine.

4.3 Putki Washery (Prime coking coal) - Capacity 3.0 MT/annum

The costs are based on the feasibility report (Updated cost

estimates) for the washery, prepared by CMPDI in February 1987. The costs have been updated to January 1989 using the following indices:

Item	2/87	1/89
i) Wholesale price index	376.6	438.1
ii) Machinery index	344.1	395.2
iii) Vehicles index	413.3	493.9
iv) Consumer price index	143.0	165.0

All capital costs have been reduced to 55.3% of the total costs to obtain costs for a washing capacity of 1.6 MT/a. Which is the output from the mine. The operating costs have been suitably modified for the reduced capital cost and capacity. The phasing of capital expenditure is given in **Annexure 4.2.** The raw coal feed to the washery will have an ash content of 29% and the clean coal will have an ash content of 17.0%. The yield of clean coal and middling are 49.8% and 32.9% respectively.

4.4 **Block II Opencast Mine (Prime coking coal). Capacity 2.5 MT/a:**

The cost figures are based on the capital costs given in the Revised Project Report for the mine prepared in July 1988 by CMPDI. The costs have been updated to January 1989 based on the following indices:

Item	7/88	1/89
i) Wholesale price index	432.3	438.1
ii) Machinery index	377.0	395.2
iii) Vehicles index	475.0	493.9
iv) Consumer price index	161.0	165.0

The financial operating costs have been computed based on the ixed and operating costs given in the report. The economic capital osts are used while computing economic operating costs. **Annexure 4.3** hows the phasing of capital expenditure.

4.5 **Madhuband Washery (Prime coking coal). Capacity 2.5 MT/a**

The costs are based on the feasibility report for Madhuband washery prepared in June 1981 and updated in February 1984 by CMPDI. The costs have been updated to January 1989 prices based on the following indices:

Item	2/84	1/89
i) Wholesale price index	305.0	438.1
ii) Machinery index	260.0	395.2
iii) Vehicles index	329.0	493.9
iv) Consumer price index	105.0	165.0

The financial operating costs have been computed based on the fixed and variable operating costs given in the report. The economic operating costs are based on the economic capital cost. The phasing of capital expenditure is given in **Annexure 4.4**. The raw coalfeed to the washery will have an ash content of 29.5% and clean coal ash will be 17%. The yield of clean coal and middlings are 47.5% and 37.6% respectively.

4.6 **Rajrappa Opencast Mine (Medium coking coal). Capacity 2.6 MT/a:**

The costs are based on the Revised Cost Estimates for Rajrappa Opencast project prepared by CMPDI in October, 1988. The costs have been updated to January 1989 using the following indices.

Item	10/88	1/89
i) Wholesale price index	439.4	438.1
ii) Machinery index	381.2	395.2
iii) Vehicles index	490.1	493.9
iv) Consumer price index	165.0	165.0

The financial operating costs have been computed from the operating costs given in the report. The economic operating costs are based on the economic capital cost and output. The phasing of capital expenditure is given in **Annexure 4.5**.

4.7 **Rajrappa Washery: (Medium coking coal) capacity 3 MT/a:**

The costs are based on the Revised Cost Estimates for Rajrappa washery prepared by CMPDI in February 1987. The costs have been updated to January 1989 using the following indices:

Item	2/87	1/89
i) Wholesale price index	376.6	438.1
ii) Machinery index	344.1	395.2
iii) Vehicles index	490.1	493.9
iv) Consumer price index	143.0	165.0

The financial operating costs have been computed based on the fixed and variable operating costs given in the report. The economic operating costs are based on the economic capital costs and output. The phasing of capital expenditure is given in **Annexure 4.6**. The raw coal feed to the washery will have an ash content of 27% and the clean coal will have 16.6% ash. The yield of clean coal and middlings are 53.8% and 42.4% respectively.

4.8 **Kedla Washery (medium coking coal) capacity 2.6 MT/a**

The costs are based on the Revised Cost Estimates for Kedla Washery prepared by CMPDI in January 1990. The costs have been adjusted to January, 1989 using the following indices:

Item	1/90	1/89
i/ Wholesale price index	468.8	438.1
ii/ Machinery price index	372.2	395.2
iii/ Vehicles	452.2	493.9
iv/ Consumer price index	176.0	165.0

The financial operating costs have been computed based on the fixed and variable operating costs given in the report. The economic operating costs are based on the economic capital costs and output. The phasing of capital expenditure is given in **Annexure 4.7**. The raw

coal feed will have an ash content of 31.5% and the clean coal ash will be 17%. The yield of clean coal and middlings are 46% and 29% respectively.

4.9 Coking Coal Import Facilities at Vishakapatnam Port - 3.5 MT/a capacity:

A feasibility report has been prepared by Howe (India) Pvt.Ltd. for SAIL and VSP on "Coking coal import facilities at Vizag port - a techno-economic appraisal in January 1987. The capital costs for the unloading facility at Vishakapatnam have been taken from this report. The costs have been updated to January 1989 based on the following indices. The financial costs have also been computed from the report. The economic operating cost is based on economic capital costs .

	Item	1/87	1/89
1.	Wholesale price index	377.7	438.1
2.	Manufactured products index	363.7	411.0
3.	Consumer price index	140.0	165.0

CHAPTER 5
Comparative Evaluation of the Costs of Coking Coal Supplies

5.1 The net present value and cost of clean coal at the washery end from the following options is evaluated.

1. Putki-Baliari mine and Putki washery (prime coking)
2. Block II opencast mine & Madhuband washery (prime coking)
3. Rajrappa opencast mine and Rajrappa washery (medium coking)
4. Typical opencast mine in Hazari bagh area and Kedla washery (medium coking)

For each option, the cost of clean coal has been calculated based on the net present values of the total costs and total clean coal production using a discount rate of 12%. The discounted cost of middling has been deducted from the total system cost to give credit to middling production. The costs have been worked out for 100% and 85% capacity utilisation of mine and washery.

5.2 Putki-Baliari Mine and Putki Washery

Annexure 5.1 lists the phased capital and operating costs for the mine and washery. The financial cost of clean coal works out to Rs. 1326.15/tonne at 100% capacity utilisation and Rs.1534.26/tonne at 85% capacity utilisation. The economic cost works out to Rs. 1134.21/tonne and Rs. 1313.55/tonne at 100% and 85% capacity utilisation respectively.

5.3 Block II Mine and Madhuband Washery

Annexure 5.2 lists the phased capital and operating costs for the mine and washery. The financial cost of clean coal works out to Rs. 675.05/tonne and Rs.788.02/tonne at 100% and 85% capacity utilisation respectively. The economic cost works out to Rs. 592.33 and Rs. 688.67 at 100% and 85% capacity utilisation respectively.

5.4 Rajrappa Opencast Mine and Washery

Annexure 5.3 lists the phased capital and operating costs for the mine and washery. The economic cost of clean coal works out to Rs. 523.37/tonne at 100% mine capacity utilisation and 85% washery capacity utilisation.

5.5 2.5 MT/a Opencast Mine and Kedla Washery

Annexure 5.4 lists the phased capital and operating costs for the Rajrappa mine and kedla washery. The financial cost of clean coal works out to be Rs.754.36/tonne and Rs.878.64/tonne at 100% and 85% capacity utilisation respectively. The economic cost works out to Rs. 635.79/tonne and Rs. 741.36/tonne at 100% and 85% capacity utilisation respectively.

5.6 Net Present Values and Cost of Clean Coal at Different Washeries

The net present values (npv) of the total financial cost and economic cost of the different sources using a discount rate of 12% are given in the tables below. The tables also show the cost of clean coal from each washery:

Table 33: npv at 12% Discount Rate for Prime and Medium Coking Coal Washeries (Financial Cost)

Mine + Washery	Total discounted cost (Rs.Million)		Total discounted clean coal production (MT)		Cost of clean coal(Rs./ton)		Cost of clean coal after taking royalty etc. (Rs./tonnes)	
Capacity utilisation	100%	85%	100%	85%	100%	85%	100%	85%
1. Putki-Baliari Mine + Putki washery	5006.2	4924.9	3.77	3.21	1326.15	1534.26	1784.53	2064.57
2. Block II Mine + Madhuband washery	1888.9	1865.2	2.78	2.36	675.05	788.02	857.41	1000.90
3. Rajrappa mine + Rajrappa washery	-	3715.7		5.97	-	621.87	-	790.47
4. 2.6 MT/a opencast mine + Kedla washery	3825.5	3813.3	5.11	4.34	754.36	878.64	958.04	1115.87

Note: Royalty, cess, stowing excise duty and sales tax etc.are levied on raw coal and this works out to 48.5% of the raw coal cost. This additional cost is loaded on the cost of clean coal based on its yield.

Table 34: npv at 12% Discount Rate for Prime and Medium Coking Coal Washeries (Economic Cost)

Mine + Washery	Total discounted cost (Rs.Million)		Total discounted clean coal production (MT)		Cost of clean coal(Rs./ton)	
Capacity utilisation	100%	85%	100%	85%	100%	85%
1. Putki-Baliari Mine + Putki washery	4281.6	4216.5	3.77	3.21	1134.21	1313.55
2. Block II Mine + Madhuband washery	1649.0	1630.1	2.78	2.37	592.33	688.67
Average cost of prime coking coal	-	-	-	-	**863.27**	**1001.11**
3. Rajrappa mine + Rajrappa washery	-	3129.6	-	5.97	-	523.87
4. 2.6 MT/a opencast mine + Kedla washery	3248.9	3217.5	5.11	4.34	635.79	741.36

As can be seen from the table, Putki mine+washery and Block II mine+Madhuband washery appear to be extreme cases so far as cost of clean coal is concerned. Therefore, it is assumed that the average cost of these two mine+washery combination will represent the average cost of prime coking coal supplies from Jharia coalfield. This average cost of prime coking coal is taken for comparison with imported coal. For medium coking coal the combination of 2.60 MT opencast mine in Hazaribagh area and Kedla washery is taken as representative of future medium coking coal washeries. For convenience, the cost figures of Rajrappa opencast mine has been taken since the costs will be similar to opencast mines which will feed Kedla washery. The cost of medium coking coal from Kedla washery is taken for comparison with imported coal.

5.7 New Coal Unloading Berth at Vishakapatnam Port for Imported Coal

The Australian coking coal is assumed to have an ash content of 10% with superior coking characteristics. The delivered cost at Vishakapatnam port is taken as US$ 70 per tonne (Coal price = $ 52 + ocean freight = $ 18). The net present value of the total costs of the coal handling arrangement at Vishakapatnam port and the cost per tonne are given in Table 35 below. The costs have been worked out separately taking costs without premium on foreign exchange component (FEC) and with 25% premium on FEC. **Annexure 5.5** lists the capital and operating costs for the unloading berth at the port.

Table 35: npv at 12% Discount Rate for a New General Cargo Berth in Outer Harbour at Vishakapatnam Port for Handling Imported Coking Coal (3.5 MT/annum)

	Total discounted cost (Rs.Million)	Total discounted coal handled (MT)	Cost of coal handled(Rs/T)
Financial cost	2374.582	20.069	118.32
Economic cost	2021.394	20.069	100.72
Economic cost (25% on FEC)	2064.813	20.069	102.89

The financial and economic cost of imported coal at Vishakapatnam port after taking into account port handling charges and custom duty on coal (5%) are given in Table 36 below:

Table 36: Cost of Imported Coal at Vishakapatnam Port

(Rs/tonne)

Item	No premium on FEC		25% premium on FEC	
	Financial	Economic	Financial	Economic
C I F value	1155.00	1155.00	1443.75	1443.75
Customs duty (5%)	57.75	-	57.75	-
Port handling charges	118.32	100.72	120.32	102.89
Total	1331.07	1255.72	1621.50	1546.64

5.8 Delivered Cost of Prime, Medium and Imported Coal at Steel Plants

All prime coking coal is supplied from Jharia coalfield and all medium coking coal (except Nandan washery) is supplied from Jharia, Bokaro and Ramgarh coalfields. For convenience the source of indigenous coal supply is taken as Dhanbad. Imported coal can be supplied from Vishakapatnam, Paradip and Hadia port. The nearest port from the steel plants is taken as the source of supply.

The rail distances from Dhanbad to the steel plants and from different ports to the steel plants are given in **Table 37** below:

Table 37: Rail Distance from Source of Supply to Steel Plants (Km)

Steel Plants	BSP	RSP	BSL	DSP	IISCO	VSP
Supply Source:						
Dhanbad	778	292	50	101	64	994
Vishakapatnam	551	657	944	1011	964	-
Paradip	748	509	563	635	528	-
Haldia	876	435	389	298	320	-

The economic rail transportation cost is taken as 20 paisa per tonne based on a RITES study. The rail transport cost from the source of supply to the steel plants are given in **Table 38** below:

Table 38: Rail Transportation Cost of Coking Coal to Steel Plants (Economic cost) Rs/tonne)

Steel Plants	BSP	RSP	BSL	DSP	IISCO	VSP
Supply Source:						
Dhanbad	155.60	67.40	10.00	20.20	12.80	198.80
Vishakapatnam	110.20	131.40	188.80	202.20	192.80	-
Paradip	146.60	101.80	112.60	127.00	105.60	-
Haldia	175.20	87.00	77.80	59.60	64.80	-

The delivered economic cost of prime, medium and imported coal at the steel plants is given in Table 39 below. The cost of indigenous prime and medium/semi coking coals are multiplied by a factor of 1.4 for comparison with the cost of imported coal. This factor has been used by CMPDI for conversion of indigenous coking coal quantity to equivalent imported coal. This factor is assumed to reflect the superior quality of imported coal.

Table 39: Delivered Cost of Coal at Steel Plants
(Economic cost) (Rs./tonne)

Steel Plant	Cap. Utili-zation	Prime coking Cost	Prime coking cost x 1.4	Medium coking Cost	Medium coking cost x 1.4	Imported coal No premium on FEC	Imported coal 25% premium on FEC	
BSP	(100%)	1018.87	1426.42	791.39	1107.15	1365.92	1656.84	(Viza
	(85%)	1156.71	1619.39	896.96	1255.74			
RSP	(100%)	930.67	1302.94	703.19	984.47	1387.12	1678.04	(Viza
	(85%)	1068.51	1495.91	808.76	1132.26	1357.52	1648.44	(Parad
BSL	(100%)	873.27	1222.58	645.79	904.11	1333.52	1624.44	(Haldi
	(85%)	1011.11	1415.55	751.36	1051.90			
DSP	(100%)	883.47	1236.86	655.99	918.39	1315.32	1606.24	(Haldi
	(85%)	1021.31	1429.83	761.56	1066.18			
IISCO	(100%)	876.07	1226.50	648.59	908.03	1319.72	1610.64	(Haldi
	(85%)	1013.91	1419.47	754.16	1055.82			
VSP	(100%)	1062.07	1416.90	834.59	1168.43	1255.72	1546.64	(Viza
	(85%)	1199.91	1679.87	940.16	1316.22			

Conclusions

1. **Economic cost of coal supplies:**

a) **Prime coking coal - 85% mine and washery capacity utilisation**

i) The economic cost of prime coking coal at BSP is higher than the cost of imported coal (without premium on FEC) and marginally lower than the cost of imported coal (with 25% premium on FEC)

ii) At RSP, BSL, DSP and IISCO, the economic cost of prime coking coal is higher than the cost of imported coal (without premium on FEC) from the nearest port, but it is lower than the cost of imported coal (with 25% premium on FEC)

iii) At VSP, the cost of prime coking coal is substantially higher than the cost of imported coal (without and with premium on FEC).

b) **Prime coking coal - 100% mine and washery utilisation**

i) At BSP, the cost of prime coking coal is higher than the cost of imported coal (without premium on FEC) but lower as compared to the cost of imported coal (with 25% premium on FEC)

ii) At RSP, BSL, DSP and IISCO, the costfs of prime coking coal is lower than the cost of imported coal (without premium on FEC) and substantially lower than the cost of imported coal (with 25% premium on FEC).

iii) At VSP the cost of prime coking coal is much higher than the cost of imported coal (without premium on FEC) but lower than the cost of imported coal (with premium on FEC).

c) **Medium coking coal - 85% mine and washery capacity utilisation**

i) The economic cost of medium coking coal at BSP, BSL, RSP, DSP, IISCO is substantially lower than the cost of imported coal (with and without premium on FEC);

ii) At VSP, the cost of medium coking coal is higher than the cost of imported coal (without premium on FEC) but is considerably lower than the cost of imported coal (with 25% premium on FEC)

d) **Medium coking coal - 100% mine and washery capacity utilisation**

i) The economic cost of medium coking coal at all the steel plants is substantialy lower than the cost of imported coal (with without premium on FEC).

ANNEXORE-1

Demand Projections Submitted by Different Agencies

(000TONNES)

Products	1989-90				1994-95				1999-2000			
	SAIL	NCAER	Pl.Com.	FINAL	SAIL	NCAER	Pl.Com.	FINAL	SAIL	NCAER	Pl. Com.	FINAL
1. Bars & Rods	5,700	5,560	5,298	5,600	7,700	7,530	7,073	7,600	10,200	10,272	9,888	10,250
2. Structurals	1,900	2,120	2,035	1,950	2,400	2,685	2,603	2,650	2,900	3,470	3,537	3,320
3. Rly. Materials	810	810	560	810	810	810	689	810	810	862	913	860
Sub-Total	8,410	8,490	7,893	8,360	10,910	11,025	10,365	11,060	13,910	14,604	14,338	14,430
4. Plates	1,410	1,535	1,474	1,450	1,840	2;240	2,055	2,020	2,250	3,265	3,091	2,730
5. H.R. Coils/ Strips/Sheets	2,280 (1780) (500)	2,515	2,357	2,450 (1900) (550)	3,000 (2300) (700)	3,650	3,648	3,450 (2700) (750)	4,000 (3015) (985)	5,236	5,046	4,825 (3800) (1025)
6. CR Coils/Sheets	1,350	1,400	1,218	1,400	1,925	2,100	1,799	2,000	2,600	3,140	2,900	2,900
7. GP/GC Sheets	450	450	429	450	620	675	615	640	920	1,025	953	930
8. Elec. St. Sheets	190	190	141	170	250	230	189	250	350	330	260	360
9. Tin Plates	275	300	196	300	320	350	218	350	400	400	258	400
10. Pipes (L. Dia)	220	210	198	220	260	230	263	300	310	400	368	450
Sub-Total	6,175	6,600	6,013	6,440	8,285	9,535	8,787	9,010	10,830	13,796	12,983	12,595
ished Steel	14,585	15,090	13,906	14,800	19,125	20,560	19,152	20,070	24,740	28,400	27,211	27,025

Note: The figures in brackets indicate the breakup of HR Coils/Strips and H.R. Sheets respectively.

Existing and New Manufacturers of Sponge-iron

		Capacity (Million Tonnes)	Coal required (Million Tonnes)
I.	Coal-based		
A.	Existing units		
	1. Sponge iron India Ltd.	0.06	0.10
	2. Orissa Sponge Iron	0.15	0.15
	3. IPITATA Sponge Iron Ltd. Jamshedpur	0.12	0.17
B.	New Units		
	4. Bihar Sponge Iron Ltd., Chandil	0.27	0.27
	5. Sunflag iron and steel Co.Ltd. Maharashtra	0.45	0.60
C.	New Schemes likely to come up		
	6. Jindal strips Ltd., Haryana	0.15	0.18
	7. Century Textiles and Ind.Ltd., Bilaspur	0.30	0.40
	8. Gold Star & Alloys Ltd., Vizag	0.30	0.30
	9. Raipur Alloys & Steel, Raipur, M.P.	0.06	0.10
	10. Poddar Projects Ltd., Badrachalam, A.P.	0.12	0.19
	11. Hindustan Electrographics Ltd. Dung, M.P.	0.15	0.21
	12. Steel Complex Ltd., Kerala	0.03	0.04
	13. Monnet4 International Ltd. Raipur, MP	0.15	0.22
	14. Jindal Strips, Raigarh	0.15	0.18
		2.46	3.11
II.	Gas based units		
A.	New Schemes under construction		
	1. Essar Gujarat	0.88	
	New Schemes likely to come up		
	2. Vikram Steel	0.60	
	3. Bharat Forge	0.60	
	4. Reliance Industries	0.60	
	Total	2.68	
	Grand Total	5.14	

Source: Department of Coal

ANNEXURE 2.1

Hot Metal Production and Coal Requirement

	1994-95				1999-2000			
	H M Prod. (MT)	Coke Rate T/THM	Coal:HM T/THM	Coal Reqd. (MT)	HM Prod. (MT)	Coke Rate T/THM	Coal:HM T/THM	Coal Reqd. (MT)
BSP	4.41	0.69	1.12	4.93	5.12	0.61	0.99	4.93
BSL	4.72	0.69	1.12	5.28	5.25	0.61	0.99	5.28
DSP	1.89	0.78	1.26	2.37	2.40	0.67	1.09	2.37
RSP	1.84	0.83	1.35	2.48	3.18	0.70	1.14	2.48
IISCO	2.20	0.74	1.20	2.64	2.20	0.74	1.20	2.64
VSP	3.40	0.73	1.19	4.05	3.40	0.73	1.19	4.05
Total	18.46	-	-	21.75	21.55	-	-	22.75

Note: Projections are based on SAIL Plan and Working Group Report.

ANNEXURE 2.2

Categorywise Coal Demand for SAIL and VSP

(Million Tonnes)

Steel Plant			1994-95	1999-2000
Gradewise Coal Requirement:				
BSP			4.93	5.08
i)	Prime	33%	1.63	1.42
ii)	Medium	35%	1.73	1.78
iii)	Semi	7%	0.34	0.36
iv)	Imported	25%	1.23	1.52
BSL			5.28	5.21
i)	Prime	30%	1.59	1.04
ii)	Medium	47%	2.48	2.45
iii)	Semi	3%	0.16	0.16
iv)	Imported	20%	1.05	1.56
DSP			2.37	2.48
i)	Prime	45%	1.07	0.87
ii)	Medium	30%	0.71	0.75
iii)	Semi	5%	0.12	0.12
iv)	Imported	20%	0.47	0.74
RSP			2.47	32.9
i)	Prime	30%	0.74	0.82
ii)	Medium	40%	0.99	1.32
iii)	Semi	75	0.12	0.16
iv)	Imported	25%	0.62	0.99
IISCO			2.64	2.64
i)	Prime	50%	1.33	1.19
ii)	Medium	30%	0.79	0.79
iii)	Semi	105	0.26	0.26
iv)	Imported	10%	0.26	0.40
SAIL			17.70	18.70
i)	Prime	33%	6.34	5.34
ii)	Medium	35%	6.70	7.08
iii)	Semi	7%	1.01	1.06
iv)	Imported	25%	3.65	5.22
VSP			4.03	4.03
i)	Prime	35%	1.41	1.41
ii)	Medium	45%	1.81	1.81
iii)	Imported	20%	0.81	0.81
SAIL and VSP			21.73	22.73
i)	Prime		7.76	6.75
ii)	Medium		8.50	8.89
iii)	Semi		1.01	1.06
iv)	Imported		4.46	6.03

Notes: Categorywise distribution is based on SAIL Plan and Working Group Report for VSP

ANNEXURE 2.3

Hot Metal Production Plan and Coal Requirement for SAIL Plants

Steel Plant	1989-90 (Est.)	1994 - 95 Max	1994 - 95 Min	1999-2000 Max (Scenario 1)	1999-2000 Min (Scenario 1)	1999-2000 Max (Scenario 2)	1999-2000 Min (Scenario 2)
1. BSP							
i) Hot Metal Prod.(MT)	3.494	3.876	3.672	4.30	4.085	4.30	4.085
ii) Coke Rate T/THM	0.69	0.69	-	0.65	-	0.61	-
iii) Coal: Hot Metal T/THM	1.119	1.119	-	1.05	-	0.993	-
iv) Coal Requirement (MT)	3.91	4.34	4.11	4.54	4.31	4.27	4.06
2. BSL							
i) Hot Metal Prod.(MT)	3.269	4.356	4.126	4.585	4.356	4.585	4.356
ii) Coke Rate T/THM	0.67	0.69	-	0.65	-	0.61	-
iii) Coal: Hot Metal T/THM	1.09	1.119	-	1.05	-	0.993	-
iv) Coal Requirement (MT)	3.56	4.87	4.65	4.84	4.59	4.55	4.32
3. DSP							
i) Hot Metal Prod.(MT)	1.062	1.360	1.19	1.36	1.19	1.36	1.19
ii) Coke Rate T/THM	0.865	0.77	-	0.70	-	0.64	-
iii) Coal: Hot Metal T/THM	1.62	1.256	-	1.136	-	1.034	-
iv) Coal Requirement (MT)	1.72	1.71	1.49	1.54	1.35	1.41	1.23
4. RSP							
i) Hot Metal Prod.(MT)	1.242	1.360	1.280	2.21	2.08	2.21	2.08
ii) Coke Rate T/THM	0.73	0.73	-	0.68	-	0.64	-
iii) Coal: Hot Metal T/THM	1.185	1.185	-	1.104	-	1.034	-
iv) Coal Requirement (MT)	1.47	1.61	1.52	2.44	2.30	2.28	2.15
5. (a) IISCO (with renovation)							
i) Hot Metal Prod.(MT)		1.384	1.211	1.643	1.557	1.643	1.557
ii) Coke Rate T/THM		0.74	-	0.74	-	0.74	-
iii) Coal: Hot Metal T/THM		1.20	-	1.20	-	1.20	-
iv) Coal Requirement (MT)		1.66	1.45	1.97	1.87	1.97	1.87
5. (b) IISCO (without renovation)							
i) Hot Metal Prod.(MT)	0.669	0.845	0.65	0.845	0.65	0.845	0.65
ii) Coke Rate T/THM	1.021	0.91	-	0.91		0.91	-
iii) Coal: Hot Metal T/THM	1.66	1.48	-	1.48		1.48	-
iv) Coal Requirement (MT)	1.11	1.25	0.96	1.25	0.96	1.25	0.96
6. (a) SAIL with IISCO renovation							
i) Hot Metal Prod.(MT)		12.336	11.479	14.1	13.27	14.1	13.27
ii) Coke Rate T/THM		0.71	-	0.67	-	0.63	-
iii) Coal: Hot Metal T/THM		1.15	-	1.09	-	1.03	-
iv) Coal Requirement (MT)		14.19	13.22	15.33	14.22	14.48	13.63
6. (b) Without IISCO renovation							
i) Hot Metal Prod.(MT)	9.736	11.797	10.918	13.302	12.363	13.302	12.363
ii) Coke Rate T/THM	0.74	0.72	-	0.68		0.64	-
iii) Coal: Hot Metal T/THM	1.21	1.17	-	1.10		1.03	-
iv) Coal Requirement (MT)	11.77	13.78	12.73	14.68	13.6	13.76	12.72

MT = Million Tonnes THM = Tonne Hot Metal (Ref.Table 13)

b) For 1999-2000: Scenario - 1 : Coke rate as per SAIL Plan assuming 15% ash in coal blend;

Scenario - 2 : Coke rate is the average of 1989 & 1999-200 as above

Categorywise Coal Demand for SAIL Steel Plants

(Million Tonnes)

Steel Plant			1994-95	1999-2000 Scenario 1	1999-2000 Scenario 2
1.	BSP				
	Coal Requirement		4.22	4.42	4.17
	i) Prime	33%	1.39	1.46	1.38
	ii) Medium	35%	1.47	1.55	1.46
	iii) Semi	7%	0.30	0.31	0.29
	iv) Imported	25%	1.06	1.10	1.04
2.	BSL				
	Coal Requirement		4.76	4.71	4.43
	i) Prime	30%	1.43	1.41	1.33
	ii) Medium	47%	2.24	2.21	2.08
	iii) Semi	3%	0.14	0.15	0.13
	iv) Imported	20%	0.95	0.94	0.89
3.	DSP				
	Coal Requirement		1.60	1.44	1.32
	i) Prime	45%	0.72	0.65	0.59
	ii) Medium	30%	0.48	0.43	0.40
	iii) Semi	5%	0.08	0.07	0.07
	iv) Imported	20%	0.32	0.29	0.26
4.	RSP				
	Coal Requirement		1.58	2.37	2.22
	i) Prime	30%	0.47	0.71	0.67
	ii) Medium	40%	0.63	0.95	0.89
	iii) Semi	5%	0.09	0.12	0.11
	iv) Imported	25%	0.39	0.59	0.55
5(a)	IISCO (with renovation)				
	Coal Requirement		1.55	1.92	1.92
	i) Prime	50%	0.77	0.96	0.96
	ii) Medium	30%	0.47	0.58	0.58
	iii) Semi	10%	0.16	0.19	0.14
	iv) Imported	10%	0.15	0.19	0.19
5(b)	IISCO/without renovation		0.65	0.65	0.65
	i) Prime	50%	0.32	0.32	0.32
	ii) Medium	30%	0.20	0.20	0.20
	iii) Semi	10%	0.07	0.07	0.07
	iv) Imported	10%	0.06	0.06	0.06
6(a)	SAIL(with IISCO renovation)		13.71	14.88	14.06
	i) Prime		4.78	5.19	4.93
	ii) Medium		5.29	5.72	5.41
	iii) Semi		0.77	0.84	0.79
	iv) Imported		2.87	3.11	2.93
6(b)	SAIL(without IISCO renovation)		12.81	13.59	12.79
	i) Prime		4.33	4.55	4.29
	ii) Medium		5.02	5.34	5.03
	iii) Semi		0.68	0.72	0.67
	iv) Imported		2.78	2.98	2.80

Notes: i) Gradewise distribution is based on SAIL Corporate Plan figures for 1994-95 and the same is assumed for 1999-2000.

ANNEXURE 2.5

Categorywise coal demand based on optimal blend

(Million Tonnes)

Steel Plant			1994-95	1999-2000 Scenario 1	1999-2000 Scenario 2
1.	BSP		4.22	4.42	4.17
	i) Prime	25%	1.05	1.10	1.04
	ii) Medium	30	1.27	1.33	1.25
	iii) Semi	5	0.21	0.22	0.21
	iv) Imported	40	1.69	1.77	1.67
2.	BSL		4.76	4.71	4.43
	i) Prime	30	1.43	1.42	1.32
	ii) Medium	45	2.14	2.12	2.00
	iii) Semi	5	0.24	0.24	0.22
	iv) Imported	20	0.95	0.93	0.89
3.	RSP		1.58	2.37	2.22
	i) Prime	28	0.44	0.66	0.62
	ii) Medium	35	0.55	0.83	0.78
	iii) Semi	5	0.08	1.12	0.11
	iv) Imported	32	0.51	0.76	1.71
4.	DSP		1.60	1.44	1.32
	i) Prime	45	0.72	0.65	0.59
	ii) Medium	30	0.48	0.43	0.39
	iii) Semi	5	0.08	0.07	0.08
	iv) Imported	22	0.32	0.29	0.26
5(a)	IISCO (with renovation)		1.55	1.92	1.92
	i) Prime	50%	0.77	0.96	0.96
	ii) Medium	30	0.47	0.58	0.58
	iii) Semi	10	0.16	0.19	0.19
	iv) Imported	10	0.15	0.19	0.19
5(b)	IISCO(without renovation)		0.65	0.65	0.65
	i) Prime		0.32	0.32	0.32
	ii) Medium		0.21	0.21	0.21
	iii) Semi		0.06	0.06	0.06
	iv) Imported		0.06	0.06	0.06
6(a)	SAIL(with IISCO renovation)		13.71	14.86	14.06
	i) Prime		4.41	4.79	4.53
	ii) Medium		4.91	5.31	5.00
	iii) Semi		0.77	0.84	0.81
	iv) Imported		3.62	3.94	3.72
7.	SAIL(without IISCO renovation)		12.81	13.59	12.79
	i) Prime		3.96	4.15	3.89
	ii) Medium		4.65	4.92	4.63
	iii) Semi		0.67	0.71	0.68
	iv) Imported		3.53	3.81	3.59

Note: 1) Gradewise distribution is based on optimal blend derived for BSP, BSL and RSP. For DSP and IISCO it is based on SAIL Plan figures for 1994-95.

Annexure 3.1

Coalfield wise Coking Coal reserves
(status as on 1.1.1989)

(Million Tonnes)

Coalfield	Depth (meter)	Reserves Proved	Indicated	Inferred	Total
1. Raniganj					
Medium coking	0-600	222.0	82.0	3.0	307.0
	600-1200		4.0	247.0	257.0
Blendable	0-600	97.0	132.0	54.0	283.0
	600-1200	27.0	256.0	506.0	789.0
Total	0-1200	124.0	388.0	560.0	1072.0
2. Jharia					
Prime	0-600	3659.0	380.0		4039.0
	600-1200	512.0	749.0		1261.0
Total	0-1200	4171.0	1129.0		5300.0
Medium	0-600	3758.0	309.0		4067.0
	600-1200	242.0	1855.0		2097.0
Total	0-1200	4000.0	2164.0		6164.0
3. East Bokaro					
Medium	0-300	1361.1	1040.5	40.4	2442.2
	300-600	216.5	1051.8	40.4	1308.7
	600-900	254.2	406.1		660.4
Total	0-900	1831.9	2498.4	80.9	4411.2
4. West Bokaro					
Medium	0-300	2292.5	1586.0	28.6	3907.1
	300-600	287.4	142.9	5.8	436.1
Total	0-600	2579.9	1728.9	34.4	4343.2
5. Ramgarh					
Medium	0-300	360.6	182.7	0.5	543.9
Semi	300-600		336.2	52.9	389.1
Total	0-600	360.6	518.9	53.4	932.9
6. North Karanpura					
Medium	0-300		1652.8	267.4	1920.2
	300-600		1143.2	294.1	1437.2
Total	0-600		2795.9	561.5	3357.4
7. South Karampura					
Medium	300-600		203.3	37.5	234.9
8. Pench - Kanhan					
Semi to medium	0-300	61.1		40	101.1
	300-600	42.9	64.8	58.2	165.9
Total		104.1	64.8	98.2	267.1
9. Sonhat					
Semi-Weakly caking	0-300	70.8	-	-	70.8
10. Shohagpur					
Medium	0-300	40.1	326.3		366.4
	300-600		563.2	5.7	568.9
Total	0-600	40.1	889.5	5.7	935.3

Source : CMPDI

Existing Coal Washeries in India

Sl. No.	Name of the Washery		Year of commi-ssioning	Installed capacity (mt/yr)	Operable Capacity MT/a
A.	PRIME COKING				
1.	Jamadoba	(TISCO)	1952 (Expn.1963)	1.80	1.44
2.	Lodna	(BCCL)	1955	0.40	0.44
3.	Durgapur	(SAIL)	1960	1.50	1.20
4.	Dugda-I	(BCCL)	1961	2.40	1.80
5.	Bhojudih	(BCCL)	1962	2.00	1.70
6.	Patherdih	(BCCL)	1964	2.00	1.60 2.00 (1992-93 onwards)
7.	Chasnalla	(TISCO)	1968	2.00	1.80
8.	Dugda-II	(BCCL)	1968	2.40	2.00
9.	Sudamdih	(BCCL)	1981	2.00	2.00
10.	Moonidih	(BCCL)	1983	2.00	2.00
	TOTAL			18.50	16.36
B.	MEDIUM COKING				
1.	West Bokaro	(TISCO)	1951 * 1982	2.50	2.50
2.	Kargali	(CCL)	1958 (Expn.1966)	2.72	2.72
3.	Kathara	(CCL)	1969	3.00	3.00
4.	Sawang	(CCL)	1970	0.75	0.75
5.	Gidi	(CCL)	1970	2.84	2.20
6.	Barora	(BCCL)	1982	0.42	0.42
7.	Nandan	(WCL)	1984	1.20	1.20
8.	Rajrappa	(CCL)	1988	3.00	3.00
9.	Mahuda	(BCCL)		0.63	0.63
	TOTAL			17.06	16.42

Availability of Prime Coking coal for SAIL & Vishakapatnam Steel Plants (Million Tonnes)

S.No.	Washery	89-90	90-91	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-2000
1	Dugda I & II	1.21	1.23	1.25	1.44	1.44	1.44	1.44	1.44	1.44	1.44	1.44
2	Bhojudih	1.11	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14
3	Patherdih	0.67	0.67	0.67	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
4	Sudamdih	0.69	0.81	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82
5	Moonndih	0.79	1.04	1.03	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13
6	Lodna	0.16	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
7	Madhuband	-	-	0.47	0.6	1.01	1.01	1.01	1.01	1.01	1.01	1.01
8	Pootki	-	-	-	-	0.35	1.04	1.27	1.27	1.27	1.27	1.27
9	Chasnalla	0.72	0.72	0.72	0.72	0.90	0.90	0.90	0.90	0.90	0.90	0.90
10	DSP	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
11	Total	5.80	6.31	6.90	7.59	8.53	9.22	9.45	9.45	9.45	9.45	9.45
12	Direct feed	0.20	0.20	0.20	0.08	-	-	-	-	-	-	-
13	Grand Total	6.00	6.51	7.10	7.67	8.53	9.22	9.45	9.45	9.45	9.45	9.45
14	Ash % (average)	19.00	18.50	17.00	17.50	17.00	17.00	17.00	17.00	17.00	17.00	17.00

Source : CMPDI

Annexure 3.4

Availability of Medium Coking coal for SAIL & Vishakapatnam Steel Plants (Million Tonnes)

S.No.	Washery	89-90	90-91	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-2000
1	Kargali	0.90	0.84	0.86	0.80	0.84	0.90	1.00	1.00	1.00	1.00	1.00
2	Kathara	0.70	0.73	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
3	Sawang	0.60	0.36	0.43	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
4	Gidi	1.00	1.00	1.00	0.47	0.76	0.76	0.76	0.76	0.76	0.76	0.76
5	Rajrappa	0.90	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
6	Kedla	-	-	-	0.69	1.06	1.15	1.15	1.15	1.15	1.15	1.15
7	Mohuda	0.24	0.33	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
8	Barora	0.10	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
9	Nandan	0.30	0.30	0.34	0.41	0.42	0.48	0.52	0.55	0.59	0.60	0.60
10	Direct feed	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
1	DSP	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
2	Total	5.14	5.35	5.63	5.76	6.47	6.68	6.82	6.85	6.89	6.90	6.90
3	AV. Ash %	18.50	18.00	17.50	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00

Availability of Direct feed semi-coking coal for SAIL steel plant (Million Tonnes)

No.	Project	89-90	90-91	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-2000
1	Assam (Ash 12%)	0.30	0.30	0.30	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
2	Raniganj (Ash 19.5%)	0.36	0.36	0.42	0.51	0.60	0.72	0.74	0.76	0.78	0.78	0.78
3	Total	0.66	0.66	0.72	0.80	0.89	1.01	1.03	1.05	1.07	1.07	1.07

urce : CMPDI

Scenario 1 : Coking coal balance sheet for SAIL and VSP

(Million Tonnes)

	Steel Plant	1994-95	1999-2000
1.	Coal requirement for SAIL	17.70	18.70
	i) Prime	6.34	5.34
	ii) Medium	6.70	7.08
	iii) Semi	1.01	1.06
	iv) Imported	3.65	5.22
2.	Coal requirement for VSP	4.03	4.03
	i) Prime	1.41	1.41
	ii) Medium	1.81	1.81
	iii) Semi	-	-
	iv) Imported	0.81	0.81
3.	Total coal for SAIL and VSP	21.73	22.73
	i) Prime	7.75	6.75
	ii) Medium	8.51	8.89
	iii) Semi	1.01	1.06
	iv) Imported	4.46	6.03
4.	Total wet coal for SAIL & VSP (Indigenous)		
	i) Prime	8.24	7.18
	ii) Medium	9.05	9.46
	iii) Semi	1.07	1.13
5.	Total coal availability (Indigenous)		
	i) Prime	9.22	9.45
	ii) Medium	6.68	6.98
	iii) Semi	1.01	1.07
6.	Surplus/deficit (Indigenous)		
	i) Prime	0.98	2.27
	ii) Medium	(-) 2.37	(-) 2.48
	iii) Semi	(-) 0.06	(-) 0.06
	iv) Total	(-) 1.45	(-) 0.27
	v) Eq.Imported Coal	1.04	0.19
7.	Total Import Requirement	5.50	6.22

Note: i) Wet coal requirement has been derived from dry coal assuming an average moisture content of 6% in indigenous coal

ii) Imported coal requirement is based on quality considerations and deficit in indigenous availability

ANNEXURE 3.5/2

Scenario - 2: Coking Coal Balance Sheet for SAIL and VSP

(Million Tonnes)

Steel Plant	1994-95 (a)	1994-95 (b)	1999-2000 2(a)	1999-2000 2(b)	1999-2000 1(a)	1999-2000 1(b)
1. Coal Requirement for SAIL	13.71	12.81	14.86	13.59	14.06	12.79
i) Prime	4.78	4.33	5.19	4.55	4.93	4.29
ii) Medium	5.29	5.02	5.72	5.34	5.41	5.03
iii) Semi	0.77	0.68	0.84	0.72	0.79	0.67
iv) Import	2.87	2.78	3.11	2.98	2.93	2.80
2. Coal Requirement for VSP	4.03	4.03	4.03	4.03	4.03	4.03
i) Prime	1.41	1.41	1.41	1.41	1.41	1.41
ii) Medium	1.81	1.81	1.81	1.81	1.81	1.81
iii) Semi						
iv) Import	0.81	0.81	0.81	0.81	0.81	0.81
3. Total Coal Requirement for SAIL & VSP	17.74	16.84	18.91	17.61	18.09	16.82
i) Prime	6.19	5.74	6.60	5.96	6.34	5.70
ii) Medium	7.10	6.83	7.53	7.14	7.22	6.84
iii) Semi	0.77	0.68	0.84	0.72	0.79	0.67
iv) Import	3.68	3.59	3.92	3.79	3.74	3.61
. Indigenous Wet Coal Requirement	14.94	14.10	15.92	14.70	15.26	14.05
i) Prime	6.58	6.11	7.02	6.34	6.74	6.06
ii) Medium	7.55	7.27	8.01	7.60	7.68	7.28
iii) Semi	0.81	0.72	0.89	0.76	0.84	0.71
. Indigenous Coal Availability for SAIL & VSP	16.91	16.91	17.50	17.50	17.50	17.50
i) Prime	9.22	9.22	9.45	9.45	9.45	9.45
ii) Medium	6.68	6.68	6.98	6.98	6.98	6.98
iii) Semi	1.01	1.01	1.07	1.07	1.07	1.07
. Surplus/deficit (Indigenous)						
i) Prime	2.64	3.11	2.43	3.09	2.71	3.39
ii) Medium	(-)0.87	(-)0.59	(-)1.03	(-)0.78	(-)0.70	(-)0.30
iii) Semi	0.20	0.29	0.18	0.31	0.23	0.36
iv) Total	1.97	2.81	1.58	2.62	2.24	3.45
. Import Requirement	3.68	3.59	3.92	3.79	3.74	3.61

ote: i) Wet coal requirement has been derived from dry coal assuming an average moisture content of 6% in the indigenous coal

ii) Imported coal requirement is based on quality considerations

iii) Column (a) denotes situation after IISCO renovation and column (b) denotes IISCO without renovation

iv) For 1999-2000, two situations are considered which reflect different coke rates for SAIL : 1-coke rate as per SAIL Plan and 2-Average of coke rate of 1989-90 & 1999-2000

ANNEXURE 3.5/3

Scenario-3: Coking Coal Balance Sheet for SAIL and VSP (Optimal)

(Million Tonnes)

Steel Plant	1994-95 (a)	1994-95 (b)	1999-2000 2(a)	1999-2000 2(b)	1999-2000 1(a)	1999-2000 1(b)
1. Total Coal Requirement for SAIL	13.71	12.81	14.86	13.59	14.06	12.79
i) Prime	4.41	3.96	4.79	4.15	4.53	3.89
ii) Medium	4.91	4.65	5.31	4.92	5.00	4.63
iii) Semi	0.77	0.67	0.84	0.71	0.81	0.68
iv) Import	3.62	3.53	3.94	3.81	3.72	3.59
2. Total Coal Requirement for VSP	4.03	4.03	4.03	4.03	4.03	4.03
i) Prime	1.41	1.41	1.41	1.41	1.41	1.41
ii) Medium	1.81	1.81	1.81	1.81	1.81	1.81
iii) Semi	-	-	-	-	-	-
iv) Import	0.81	0.81	0.81	0.81	0.81	0.81
3. Total Coal Requirement for SAIL & VSP	17.74	16.84	18.91	17.62	18.09	16.82
i) Prime	5.82	5.37	6.20	5.56	5.94	5.30
ii) Medium	6.72	6.46	7.12	6.73	6.81	6.44
iii) Semi	0.77	0.67	0.84	0.71	0.81	0.68
iv) Import	4.43	4.34	4.75	4.62	4.53	4.40
4. Total Wet Coal (Indigenous) Requirement for SAIL and VSP						
i) Prime	6.19	5.71	6.60	5.91	6.32	5.64
ii) Medium	7.15	6.87	7.57	7.16	7.24	6.85
iii) Semi	0.82	0.71	0.89	0.76	0.86	0.72
5. Total Coal Availability for SAIL and VSP	16.91	16.91	17.50	17.50	17.50	17.50
i) Prime	9.22	9.22	9.45	9.45	9.45	9.45
ii) Medium	6.68	6.68	6.98	6.98	6.98	6.98
iii) Semi	1.01	1.01	1.07	1.07	1.07	1.07
6. Surplus/deficit						
i) Prime	3.03	3.51	2.85	3.54	3.13	3.81
ii) Medium	(-)0.47	(-)0.19	(-)0.59	(-)0.18	(-)0.26	(-)0.13
iii) Semi	0.19	0.30	0.18	0.31	0.21	0.35
iv) Total	2.75	3.62	2.44	3.67	3.08	4.29
7. Imported Coal Requirement	4.43	4.34	4.75	4.62	4.53	4.40

Note:

i) Imported coal requirement is based on quality considerations

ii) Column (a) denotes situation after IISCO renovation and column (b) denotes IISCO without renovation

iii) For 1999-2000, two situations are considered which reflect different coke rates for SAIL: 1-coke rate as per SAIL Plan and 2-Average of coke rate of 1989-90 and 1999-2000.

Annexure 4.1

[illegible]asing o capital expenditure for Putki Mine

Mine: Putkee Grade: Prime Coking   All figure in millions of Rupees

Costs at January 1989 Prices. WPI : 438.1   CPI:165   Indices for: Machinery-395.2; Vehicles-493.9

	TOTAL	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96
	8.325	2.128	4.256	1.941							
ings											
Residential	22.245	5.645	11.290	2.658	2.652						
Service	103.319	2.996	5.991	9.433	32.627	19.645	16.313	16.313			
& Machinery	1553.200	47.006	94.012	178.169	308.379	186.475	395.908	90.478	155.328	90.349	7.095
ure & Fittings	1.828	0.609	1.218								
y Siding											
les	4.296	0.506	1.013	0.364	0.998	0.686	0.728				
cting & Boring	35.254	9.048	18.097	8.109							
pment											
ines	497.091	104.704	209.409	35.873	42.348	45.819	27.215	7.532	22.182	2.009	
Roads & Culverts	9.161	0.461	0.923	0.614	0.615	3.275	3.274				
Water Supply	12.168	0.087	0.174	1.928	1.928	1.928			3.192	2.930	
st	40.057	5.834	11.669	10.092	10.092	2.370					
AL COST											
ncial Cost	2286.943	179.025	358.051	249.181	399.640	260.198	443.438	114.323	180.702	95.288	7.09
mic Cost	1978.795	164.728	329.456	213.727	340.223	225.873	370.562	97.668	152.110	78.658	5.78

Annexure 4.2

Phasing of capital expenditure for Putki Washery

Washery: Putkee All figure in millions of Rupees

	Costs at Jan 1989 Prices					
		Wholesale Price Index			438.1	
		Machinery Price Index			395.200	
		Vehicle Price Index			493.900	
		Consumer Price Index			165.000	
	TOTAL	Upto 1986-87	1987-88	1988-89	1989-90	1990-91
Land	3.244		3.244			
Buildings						
(i) Residential	20.349		1.972	5.934	9.889	2.554
(ii) Service	114.591		16.670	33.366	44.524	20.030
Plant & Machinery	372.272		37.227	74.454	148.909	111.682
Furniture & Fittings	1.709		0.351	0.424	0.354	0.581
Railway Siding	12.644		7.586	0.759	0.632	3.667
Vehicles	1.261		0.311	0.312	0.444	0.194
Development						
(i) Mines	1.158		1.158			
(ii) Roads & Culverts	1.606		0.155	0.173	0.969	0.309
(iii) Water Supply	10.753		0.520	2.595	4.151	3.487
FRP Cost	2.731	0.800	1.931			
CAPITAL COST						
Financial Cost	542.318	0.800	71.126	118.016	209.873	142.503
Economic Cost						
no premium on forex	453.444	0.800	62.302	98.377	172.573	119.391

Annexure 4.3

Phasing of capital expenditure for Block II O C Mine

Mine:Block II   Grade: Prime Coking   All figure in mill

Costs at January 1989 Prices. WPI : 438.1
Index for: Machinery - 395.200
Vehicles - 493.9

	TOTAL	1987-88	1988-89	1989-90	1990-91	1991-92
Land	35.835	6.043	12.536	12.032	5.223	0.000
Buildings						
(i) Residential	89.975	23.824	38.981	17.352	7.430	2.389
(ii) Service	64.507	13.972	21.911	19.658	7.633	1.333
Plant & Machinery	1530.817	837.720	165.769	509.662	10.116	7.551
Furniture & Fittings	1.378	0.708	0.265	0.203	0.203	0.000
Railway Siding	0.000	0.000	0.000	0.000	0.000	0.000
Vehicles	4.253	1.711	1.360	1.181	0.000	0.000
Prospecting & Boring	20.734	7.256	11.958	1.520	0.000	0.000
Development						
(i) Mines	51.854	1.890	14.427	17.023	11.661	6.853
(ii) Roads & Culverts	15.078	2.835	6.295	3.609	2.339	0.000
(iii) Water Supply	16.255	1.160	5.087	5.087	4.921	0.000
FRP Cost	5.695	1.144	4.550	0.000	0.000	0.000
CAPITAL COST						
Financial Cost	1836.381	898.264	283.139	587.327	49.525	18.125
Economic Cost	1464.623	720.238	213.644	476.160	40.233	14.346

Annexure 4.4

Phasing of capital expenditure for Madhuband washery

Grade:Prime Coking Washery: Madhuband All figure in millions of Rupees

	Costs at Jan 1989 Pric				
		Wholesale Price Index			438.1
		Machinery Price Index			395.200
		Vehicle Price Index			493.900
		Consumer Price Index			165.000
	TOTAL	1984-85	1985-86	1986-87	
Land	0.000	0.000	0.000	0.000	
Buildings					
(i) Residential	38.065	5.711	19.032	13.322	
(ii) Service	255.219	66.656	100.947	87.616	
Plant & Machinery	607.535	153.243	243.015	211.277	
	0.000	0.000	0.000	0.000	
Furniture & Fittings	1.205	0.181	0.602	0.422	
Railway Siding	32.517	4.878	16.258	11.380	
Vehicles	2.079	0.555	1.006	0.518	
Development					
(i) Washery	2.655	2.655	0.000	0.000	
(ii) Roads & Culverts	6.186	0.927	3.093	2.166	
(iii) Water Supply	47.261	7.090	23.631	16.540	
FRP Cost	4.746	4.746	0.000	0.000	
Pilot R &D Scheme	1.672	0.836	0.836	0.000	
CAPITAL COST					
Financial Cost	999.140	247.479	408.420	343.242	
Economic Cost					
no premium on forex	849.245	213.560	344.656	291.029	
25% premium on forex	849.245	213.560	344.656	291.029	

Phasing of capital expenditure for Rajrappa O C Mine

Annexure 4 5

Mine:Rajrappa Grade: Med-ium Coking   All figure in millions of Rupees

Costs at January 1989 Prices. WPI = 438.1   CPI:165 Indices for: Machinery-395.2; Vehicles-493.9

	TOTAL	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96
nd	7.015	1.889	3.778	0.578	0.134			0.029		0.606	
ildings											
i) Residential	38.489	4.321	8.643	4.843	2.228	2.941	1.843	2.442	1.796	2.617	6.81[illegible]
ii) Service	19.834	4.499	8.999		0.528	0.300	1.923	2.716	0.051	0.817	
ant & Machinery	946.736	73.186	146.372	159.183	64.006	117.170	53.110	71.582	33.748	161.127	67.253
rniture & Fittings	1.618	0.412	0.824	0.114	0.017			0.061	0.153	0.037	
ilway Siding											
hicles	17.390	4.724	9.449	0.637	0.559	0.900	0.147	0.219	0.269		0.485
ospecting & Boring	7.374	2.458	4.916								
velopment											
i) Mines	45.850	0.075	0.150	0.166	1.089	5.359	1.190	7.643	0.044	0.007	30.128
ii) Roads & Culverts	18.439	0.828	1.656	0.623	1.438	1.031	2.832	5.512	2.867	1.651	
iii) Water Supply	5.925	0.345	0.690	4.450	0.342			0.058	0.019	0.020	
Cost	15.446	5.149	10.297								
PITAL COST											
inancial Cost	1124.117	97.887	195.774	170.593	70.342	127.702	61.045	90.262	38.948	166.882	104.68.
conomic Cost	911.359	80.094	160.188	136.450	56.332	103.193	49.426	74.644	30.940	134.606	85.487

Annexure 4.6

Phasing of capital expenditure for Rajrappa washery

Grade: Medium Coking Washery: Rajrappa All figure in millions of Rupees

Wholesale Price Index	438.1
Machinery Price Index	395.200
Vehicle Price Index	493.900
Consumer Price Index	165.000

	TOTAL	Till 3/83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89	1989-90
Land	2.282	0.627	0.449	0.080	0.064	0.140		0.922	
Buildings									
(i) Residential	13.648	10.120		0.028		0.022	0.110	2.219	1.149
(ii) Service	86.569	64.548	0.022	0.194	0.731	0.613	0.360	1.642	18.460
Plant & Machinery	247.055	113.148	24.424	30.609	22.257	3.431	1.850	8.096	43.240
Furniture & Fittings	1.373	0.197	0.010		0.093	0.255	0.013	0.017	0.788
Railway Siding	213.399	53.520	44.086	23.203	41.765	7.527	5.801	11.602	25.896
Vehicles	2.186	0.403			0.391	0.011	0.011		1.371
Development									
(i) Mines	2.359	1.732							0.626
(ii) Roads & Culverts	12.584	1.617	0.230	0.009	0.602	1.419	1.002	1.491	6.214
(iii) Water Supply	280.762	109.298	11.834	39.889	34.590	13.515	0.045	0.013	71.579
FRP Cost	16.173	9.152				1.835			5.187
CAPITAL COST									
Financial Cost	878.390	364.362	81.054	94.013	100.493	28.766	9.192	26.002	174.509
Economic Cost									
no premium on forex	819.266	333.414	76.558	88.351	96.396	28.112	8.741	22.292	165.401
25% premium on forex	819.266	333.414	76.558	88.351	96.396	28.112	8.741	22.292	165.401

Annexure 4.7

Phasing of Capital Expenditure for Kedla Washery

Washery: Kedla — All figure in millions of Rupees

Costs at	Wholesale	Price Index	438.1
Jan 1989	Machinery	Price Index	395.200
Prices	Vehicle	Price Index	493.900
	Consumer	Price Index	165.000

	TOTAL	Upto 1988-89	1989-90	1990-91	1991-92	1992-93
nd	0.494	0.478	0.000	0.016	0.000	0.000
ildings						
i) Residential	1.160	1.160	0.000	0.000	0.000	0.000
ii) Service	189.123	88.752	17.775	37.169	37.169	8.260
ant & Machinery-Indigeneous	346.647	112.021	26.150	83.390	83.390	41.696
-Imported	19.315	6.240	1.457	4.647	4.647	2.323
rniture & Fittings	1.097	0.233	0.093	0.308	0.308	0.154
ilway Siding	28.065	0.000	9.355	7.952	7.952	2.807
hicles	2.805	0.837	0.330	0.623	0.499	0.517
velopment						
i) Mines	1.305	1.133	0.047	0.062	0.063	0.000
ii) Roads & Culverts	15.287	13.286	0.549	0.726	0.726	0.000
iii) Water Supply	5.727	4.977	0.206	0.272	0.272	0.000
P Cost	3.382	2.941	0.121	0.160	0.160	0.000
APITAL COST						
Financial Cost	614.407	232.057	56.083	135.325	135.186	55.756
Economic Cost						
no premium on forex	540.564	207.410	50.600	117.840	117.701	47.013
25% premium on forex	543.174	208.253	50.797	118.468	118.329	47.327

Annexure 5.1-

Cost of Clean Coal from Putki Mine + Putki Washery

1.66 MT/a Putkee Mine & Washery

Costs at January 1989 Prices. WPI = 438.1 CPI:165 Indices for: Machinery-395.2: Vehicles-473.9

	TOTAL	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1975-96	1996-97 to 2018-19	
												Annual	Total
PRODUCTION													
Capacity	42.273			0.038	0.258	0.432	0.455	0.570	1.120	1.310	1 570	1.660	36.520
Production at100% Utilization	7.164			0.030	0.184	0.275	0.258	0.289	0.507	0.529	0.566		4.527
Mine Output & Washery Input	42.273			0.038	0.258	0.432	0.455	0.57	1.12	1.31	1.57	1.66	36.520
Discounted at 12%	7.164			0.030	0.184	0.275	0.258	0.289	0.507	0.529	0.566		4.527
Washery Output- Undiscounted	22.278			0.020026	0.135966	0.227664	0.239785	0.30039	0.59024	0.69037	0.82739	0.87482	19.246
Discounted at 12%	3.775			0.016	0.097	0.145	0.136	0.152	0.267	0.279	0.298		2.386
Middlings - Undiscounted	9.681			0.008702	0.059082	0.098928	0.104195	0.13053	0.25648	0.29999	0.35953	0.38014	8.363
Discounted at 12%	1.641			0.007	0.042	0.063	0.059	0.066	0.116	0.121	0.130		1.037
Production at 85% Utilization													
Mine Output & Washery Input	35.932			0.032	0.219	0.367	0.387	0.484	0.952	1.114	1.335	1.411	31.042
Discounted at 12%	6.089			0.026	0.156	0.233	0.219	0.245	0.431	0.450	0.481		3.848
Washery Output- Undiscounted	18.936			0.017	0.116	0.194	0.204	0.255	0.502	0.587	0.703	0.744	16.359
Discounted at 12%	3.209			0.014	0.082	0.123	0.116	0.129	0.227	0.237	0.254		2.028
Middlings - Undiscounted	8.228			0.007396	0.050219	0.084088	0.089565	0.110950	0.218008	0.254991	0.305600	0.323119	7.109
Discounted at 12%	1.394			0.006	0.036	0.053	0.050	0.056	0.099	0.103	0.110		0.881
MINE CAPITAL COST													
Financial Cost	2286.943	179.025	358.051	249.181	399.640	260.198	443.438	114.323	180.702	95.298	7.095		
Economic Cost	1978.795	164.728	329.456	213.727	340.223	225.873	370.562	97.668	152.110	78.658	5.789		
MINE ANNUAL COST													
Production at100% Utilization													
Financial Cost	11352.970			276.793	293.101	306.000	307.705	315.230	357.001	371.686	390.360	397.032	8734.674
Economic Cost	9624.496			239.318	252.395	262.738	264.105	270.940	303.632	314.926	330.390	335.730	7386.061
Production at 85% Utilization													
Financial Cost	10882.915			276.370	290.232	301.196	302.646	309.892	344.549	356.519	372.902	378.573	8328.610
Economic Cost	9247.590			238.980	250.095	258.886	260.048	265.858	293.647	303.246	315.292	320.929	7060.449
MINE TOTAL COST													
Production at100% Utilization													
Financial - Undiscounted	13639.912	179.0254	358.0509	525.9741	692.7409	566.1983	751.1430	430.5528	537.7029	466.3744	397.4552	397.0315	8734.674
Discounted at 12%	4072.870	179.025	319.688	419.303	493.079	359.829	426.219	218.131	243.230	198.361	143.326		1082.677
Economic - Undiscounted	11603.292	164.7280	329.4560	453.0453	592.6181	488.6111	634.6670	369.6089	455.7423	393.5935	336.1678	335.7300	7386.061
Discounted at 12%	3501.116	164.728	294.157	361.165	421.814	310.521	360.127	186.749	206.155	158.962	121.226		915.512
Production at 85% Utilization													
Financial - Undiscounted	13169.858	179.025	358.051	525.552	689.872	561.395	746.084	424.215	525.249	451.898	379.998	378.573	8328.610
Discounted at 12%	3993.210	179.025	319.688	418.967	491.037	356.776	423.348	214.920	237.576	182.478	137.031		1032.343
Economic - Undiscounted	11226.385	164.728	329.456	452.707	590.318	484.759	630.610	363.527	445.756	381.704	322.172	320.929	7060.449
Discounted at 12%	3437.242	164.728	294.157	360.895	420.177	308.073	357.825	184.174	201.638	154.244	116.178		875.152

Annexure 5.1/2

	TOTAL	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97 to 2018-19	
												Annual	Total
WASHERY CAPITAL COST													
Financial Cost	542.318	0.800	71.126	118.016	209.873	142.503							
Economic Cost	453.444	0.800	62.302	98.377	172.573	119.391							
WASHERY ANNUAL COST													
Production at100% Utilization													
Financial Cost	3953.252			74.792	83.935	91.167	92.123	96.902	119.760	127.656	138.462	142.202	3128.455
Economic Cost	3242.025			62.478	69.793	75.579	76.344	80.167	98.455	104.772	113.417	116.410	2561.018
Production at 85% Utilization													
Financial Cost	3689.722			74.555	82.327	88.474	89.286	93.349	112.778	119.490	128.675	131.854	2900.789
Economic Cost	3031.188			62.289	68.507	73.424	74.074	77.325	92.869	98.239	105.587	108.131	2378.875
WASHERY TOTAL COST													
Production at100% Utilization													
Financial - Undiscounted	4495.570	0.800112	71.12635	192.8080	293.8081	233.6693	92.12268	96.90208	119.7600	127.6564	138.4620	142.2024	3128.455
Discounted at 12%	1220.444	0.800	63.506	153.705	209.127	148.501	52.273	49.094	54.173	51.558	49.931		387.776
Economic - Undiscounted	3784.342	0.800112	71.12635	180.4943	279.6661	218.0814	76.34366	80.16741	98.45491	104.7724	113.4174	116.4099	2561.018
Discounted at 12%	1074.978	0.800	63.506	143.889	199.061	138.595	43.319	40.615	44.536	42.316	40.899		317.442
Production at 85% Utilization													
Financial - Undiscounted	4232.040	0.800	71.126	192.571	292.200	230.976	89.286	93.349	112.778	119.490	128.675	131.854	2900.789
Discounted at 12%	1175.784	0.800	63.506	153.517	207.982	146.790	50.663	47.293	51.015	48.260	46.401		359.557
Economic - Undiscounted	3484.632	0.800	62.302	160.666	241.080	192.816	74.074	77.325	92.869	98.239	105.587	108.131	2378.875
Discounted at 12%	974.476	0.800	55.627	128.082	171.596	122.538	42.032	39.175	42.009	39.677	38.076		294.865
TOTAL COST													
Production at100% Utilization													
Financial - Undiscounted	18135.482	179.8255	429.1773	718.7821	986.5490	799.8676	843.2657	527.4549	657.4630	594.0309	535.9173	539.2340	11863.148
Discounted at 12%	5293.314	179.826	383.194	573.009	702.206	508.330	478.492	267.225	297.403	239.919	193.257		1470.453
Economic - Undiscounted	15298.760	165.5281	391.7577	613.9010	834.9850	683.5812	711.0107	448.7763	554.1972	498.3559	449.5872	452.1399	9947.0790
Discounted at 12%	4511.323	165.528	349.784	489.398	594.326	434.428	403.447	227.364	250.691	201.278	162.126		1232.954
Production at 85% Utilization													
Financial - Undiscounted	17401.898	179.826	429.177	718.123	982.072	792.371	835.370	517.563	638.027	571.298	508.672	510.427	11229.399
Discounted at 12%	5168.994	179.826	383.194	572.483	699.019	503.566	474.011	262.214	288.611	230.738	183.432		1391.899
Economic - Undiscounted	14711.017	165.528	391.758	613.373	831.398	677.575	704.685	440.851	538.625	480.142	427.759	429.060	9439.323
Discounted at 12%	4411.718	165.528	349.784	488.977	591.773	430.611	399.857	223.349	243.647	193.921	154.254		1170.017
REVENUE (Sales of Middlings)													
Production at 100% Utilization													
Financial - Undiscounted	1694.090			1.52785	10.33935	17.3124	18.23412	22.84275	44.884	52.49825	62.91775	66.5245	1463.539
(@Rs.175/T) Discounted at 12%	287.098			1.214006	7.359345	11.00234	10.34653	11.57284	20.30324	21.20316	22.68877		181.408
Economic - Undiscounted	1355.272			1.21828	8.27148	13.84992	14.5873	18.2742	35.9072	41.9986	50.3342	53.2196	1170.831
(@Rs.140/T) Discounted at 12%	229.678			0.971205	5.887476	8.801874	8.277225	9.258278	16.24259	16.96253	18.15101		145.126
Production at 85% Utilization													
Financial - Undiscounted	1439.977			1.294422	8.788447	14.71554	15.49900	19.41633	38.1514	44.62351	53.48008	56.54582	1244.008
(@Rs.175/T) Discounted at 12%	244.033			1.031905	6.255443	9.351991	8.794552	9.836920	17.25775	18.02268	19.28545		154.197
Economic - Undiscounted	1151.982			1.035538	7.030758	11.77243	12.39920	15.53307	30.52112	35.69881	42.78407	45.23666	995.207
(@Rs.140/T) Discounted at 12%	195.227			0.825524	5.004354	7.481593	7.035641	7.869536	13.80620	14.41815	15.42836		123.357
CLEAN COAL COST													
Production at100% Utilization													
Financial - Undiscounted	16441.392	179.8255	429.1773	717.2593	976.2096	782.5552	825.0316	504.6122	612.5790	541.5327	472.9996	472.7095	10399.609
Discounted at 12%	5006.216	179.8255	383.1940	571.7947	694.8467	497.3280	468.1451	255.6522	277.0996	218.7159	170.5684		1289.0457
Economic - Undiscounted	13943.488	165.5281	391.7577	612.6827	826.7135	669.7313	696.4234	430.5021	518.2900	456.3573	399.2530	398.9203	8776.2478
Discounted at 12%	4281.644	165.5281	349.7837	488.4269	588.4383	425.6263	395.1693	218.1057	234.4481	184.3150	143.9746		1087.8278
Production at 85% Utilization													
Financial - Undiscounted	15961.921	179.8255	429.1773	716.8283	973.2833	777.6554	819.8709	498.1471	599.8757	526.6743	455.1922	453.8813	9985.3905
Discounted at 12%	4924.960	179.8255	383.1940	571.4511	692.7638	494.2140	465.2167	252.3768	271.3533	212.7149	164.1469		1237.7027
Economic - Undiscounted	13559.036	165.5281	391.7577	612.3371	824.3671	665.8025	692.2854	425.3182	508.1042	444.4435	384.9746	383.8234	8444.1167
Discounted at 12%	4216.491	165.5281	349.7837	488.1514	586.7682	423.1295	392.8213	215.4794	229.8405	179.5033	138.8257		1046.6597

Annexure 5.2

Cost of clean coal from Block II O C Mine + Madhuband washery

:.5 MT/a Block II Mine & Madhuban Washery   All costs at January, 1989 prices

	TOTAL	Years 1-6	Year 7	Year 8	Year 9	Year 10	Year 11	Years 12-31 Annual	Years 12-31 Total
roduction Phasing									
aw Coal Production- 100%	52.620					1.140	1.480	2.500	50.000
Discounted	6.160					0.367	0.425		5.368
85%	44.727					0.969	1.258	2.125	42.500
Discounted	5.236					0.312	0.362		4.562
lean Coal Production-100%	23.784					0.515	0.669	1.130	22.600
Discounted	2.784					0.166	0.192		2.426
85%	20.217					0.438	0.569	0.961	19.210
Discounted	2.367					0.141	0.163		2.062
iddlings Production- 100%	19.838					0.430	0.558	0.943	18.850
Discounted	2.322					0.138	0.160		2.024
85%	16.862					0.365	0.474	0.801	16.023
Discounted	1.974					0.118	0.136		1.720
line Capital Cost									
Financial Cost	1836.381	898.264	283.139	587.327	49.525	18.125			
Discounted	607.442	218.458	128.078	237.212	17.859	5.836			
Economic Cost	1464.623	720.238	213.644	476.160	40.233	14.346			
Discounted	483.245	175.162	96.642	192.313	14.509	4.619			
ne annual Cost									
Financial Cost - 100%	7218.051					263.061	280.724	333.713	6674.265
Discounted	881.883					84.699	80.702		716.482
Economic Cost - 100%	6671.329					251.217	265.347	307.738	6154.765
Discounted	817.880					80.885	76.281		660.714
Financial Cost - 85%	6808.009					254.178	269.191	314.232	6284.640
Discounted	833.881					81.838	77.386		674.656
Economic Cost - 85%	6343.296					244.110	256.121	292.153	5843.065
Discounted	779.478					78.597	73.629		627.253
ine Total Cost									
Financial Cost - 100%	9054.431	898.264	283.139	587.327	49.525	281.186	280.724	333.713	6674.265
Discounted	1489.325	218.458	128.078	237.212	17.859	90.534	80.702		716.482
Economic Cost - 100%	8135.952	720.238	213.644	476.160	40.233	265.563	265.347	307.738	6154.765
Discounted	1301.125	175.162	96.642	192.313	14.509	85.504	76.281		660.714
Financial Cost - 85%	8644.390	898.264	283.139	587.327	49.525	272.303	269.191	314.232	6284.640
Discounted	1441.323	218.458	128.078	237.212	17.859	87.674	77.386		674.656
Economic Cost - 85%	7807.919	720.238	213.644	476.160	40.233	258.456	256.121	292.153	5843.065
Discounted	1262.723	175.162	96.642	192.313	14.509	83.216	73.629		627.253
hery Capital cost									
Financial Cost	999.140			247.479	408.420	343.242			
Discounted	357.747			99.952	147.280	110.515			
Economic Cost	849.245			213.560	344.656	291.029			
Discounted	304.243			86.253	124.286	93.704			
shery Annual Cost									
'inancial Cost - 100%	3715.088					119.183	132.678	173.161	3463.228
Discounted	448.293					38.374	38.142		371.777
:conomic Cost - 100%	3053.255					99.039	109.834	142.219	2844.382
Discounted	368.807					31.888	31.575		305.344
'inancial Cost - 85%	3401.815					112.396	123.866	158.278	3165.553
Discounted	411.619					36.189	35.609		339.822
conomic Cost - 85%	2802.653					93.610	102.786	130.313	2606.257
Discounted	339.470					30.140	29.548		279.782
hery Total Cost									
inancial Cost - 100%	4714.228			247.479	408.420	462.425	132.678	173.161	3463.228
Discounted	806.040			99.952	147.280	148.888	38.142		371.777
conomic Cost - 100%	3902.500			213.560	344.656	390.068	109.834	142.219	2844.382
Discounted	673.050			86.253	124.286	125.591	31.575		305.344
inancial Cost - 85%	4400.955			247.479	408.420	455.638	123.866	158.278	3165.553
Discounted	769.367			99.952	147.280	146.703	35.609		339.822

Costs at January 1989 Prices. WPI = 430.1 CPI:165 Indices for: Machinery-395.2; Vehicles-493.9

Annex.5.3

	TOTAL	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92 to 20[illegible]	
RODUCTION													Annual	T
apacity	74.230						0.920	1.430	2.040	2.240	2.600	2.600	2.600	6[illegible]
Discounted at 12%	11.182						0.522	0.724	0.923	0.905	0.938	0.837		
ashery Production	39.943						0.495	0.769	1.098	1.205	1.399	1.399	1.399	3[illegible]
Discounted at 12%	5.974						0.281	0.390	0.497	0.487	0.505	0.450		[illegible]
iddlings Production	31.511						0.391	0.607	0.866	0.951	1.104	1.104	1.104	26
Discounted at 12%	4.713						0.222	0.300	0.392	0.384	0.398	0.355		[illegible]
PITAL COST														
inancial cost	1336.728	97.887	195.774	170.593	70.342	127.702	61.045	90.262	38.948	166.882	104.681	212.611		
conomic Cost	1085.258	80.094	160.188	136.450	56.332	103.193	49.426	74.644	30.940	134.606	85.487	173.899		
NUAL COST														
inancial cost	14563.378						387.570	419.684	458.096	470.690	493.359	493.359	493.359	11840
conomic Cost	11768.447						313.974	339.668	370.400	380.476	398.613	398.613	398.613	9566
TAL MINE COST														
inancial cost - Undiscounted	15900.106	97.887	195.774	170.593	70.342	127.702	448.615	509.947	497.044	637.572	598.040	705.970	493.359	11840
Discounted at 12%	3164.651	97.887	174.798	135.996	50.068	81.157	254.556	258.355	224.837	257.505	215.659	227.303		1186
conomic cost - Undiscounted	12853.705	80.094	160.188	136.450	56.332	103.193	363.401	414.312	401.340	515.082	484.099	572.511	398.613	9566
Discounted at 12%	2560.826	80.094	143.025	108.777	40.096	65.581	206.203	209.903	181.546	200.033	174.571	184.333		958
SHERY CAPITAL COST														
inancial cost	878.391	121.454	121.454	121.454	81.054	94.013	100.493	28.766	9.192	26.002	174.509			
conomic Cost	819.266	111.138	111.138	111.138	76.558	88.351	96.396	28.112	8.741	22.292	165.401			
SHERY ANNUAL COST														
inancial cost	4957.086						109.995	128.121	149.800	156.908	169.702	169.702	169.702	4072
conomic Cost	4273.221						98.251	112.750	130.093	135.779	146.013	146.013	146.013	3504
TAL WASHERY COST														
inancial cost - Undiscounted	5835.476	121.454	121.454	121.454	81.054	94.013	210.488	156.886	158.992	182.910	344.212	169.702	169.702	4072
Discounted at 12%	1375.771	121.454	108.441	96.822	57.693	59.747	119.436	79.403	71.920	73.074	124.126	54.640		408
conomic cost - Undiscounted	5092.487	111.138	111.138	111.138	76.558	88.351	194.647	140.862	138.834	158.071	311.415	146.013	146.013	3504
Discounted at 12%	1228.539	111.138	99.230	88.599	54.493	56.149	110.448	71.365	62.001	63.042	112.299	47.012		351
TAL SYSTEM COST														
inancial cost - Undiscounted	21735.582	219.341	317.228	292.047	151.396	221.715	659.103	666.833	656.036	820.482	942.252	875.673	663.062	15913
Discounted at 12%	4540.422	219.341	283.239	232.818	107.761	140.904	373.993	337.838	296.757	331.379	339.786	281.943		1594
conomic cost - Undiscounted	17946.192	191.232	271.326	247.588	132.890	191.544	558.048	555.174	540.174	673.153	795.514	718.525	544.626	13071
Discounted at 12%	3789.365	191.232	242.255	197.375	94.589	121.729	316.651	281.269	244.347	271.075	286.870	231.346		1309
VENUE (from Middlings Sales)														
inancial cost - Undiscounted	5514.361						68.345	106.231	151.547	166.404	193.148	193.148	193.148	4635
(Rs.175/T) Discounted at 12%	824.719						38.781	53.820	68.552	67.208	69.651	62.188		464
conomic cost - Undiscounted	4411.489						54.676	84.985	121.237	133.123	154.518	154.518	154.518	3708
(Rs.140/T) Discounted at 12%	659.775						31.024	43.056	54.842	53.766	55.721	49.751		371
LEAN COAL COST														
inancial cost - Undiscounted	16221.221	219.341	317.228	292.047	151.396	221.715	590.758	560.602	504.489	654.078	749.104	682.525	469.914	11277.
Discounted at 12%	3715.703	219.341	283.239	232.818	107.761	140.904	335.212	284.018	228.205	264.171	270.135	219.755		1130
conomic cost - Undiscounted	13534.703	191.232	271.326	247.588	132.890	191.544	503.372	470.189	418.937	540.029	640.996	564.007	390.108	9362
Discounted at 12%	3129.589	191.232	242.255	197.375	94.589	121.729	285.627	238.213	189.506	218.109	231.150	181.595		938.

Cost of clean coal from Rajrappa Mine + Washery

Annx.5.

Cost of Clean Coal from a 2.6 MT/a Opencast Mine + Kedla Washery (capacity utilisation of Mine & Washery at 100%)

Mine:RajrappaGrade: Medium Coking All figure in millions of Rupees
Washery: Kedla

Costs at January 1989 Prices. WPI = 438.1 CPI:165 Indices for: Machinery-395.2; Vehicles-493.9

	TOTAL	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92 to 2014-15 Annual	1991-92 to 2014-15 Total
CTION														
city	74.230						0.920	1.430	2.040	2.240	2.600	2.600	2.600	62.400
uction at 85% Cap. Util.	63.096						0.782	1.216	1.734	1.904	2.210	2.210	2.210	53.040
Discounted at 12%	9.436						0.444	0.616	0.784	0.769	0.797	0.712		5.315
ery Production	29.024						0.360	0.559	0.798	0.876	1.017	1.017	1.017	24.398
Discounted at 12%	4.341						0.204	0.283	0.361	0.354	0.367	0.327		2.445
llings Production	18.298						0.22678	0.352495	0.50286	0.55216	0.6409	0.6409	0.6409	15.382
Discounted at 12%	2.737						0.129	0.179	0.227	0.223	0.231	0.206		1.541
AL COST														
ncial cost	1336.728	97.887	195.774	170.593	70.342	127.702	61.045	90.262	38.948	166.882	104.681	212.611		
omic Cost	1085.258	80.094	160.188	136.450	56.332	103.193	49.426	74.644	30.940	134.606	85.487	173.899		
L COST														
ncial cost	13862.238						378.880	406.177	438.827	449.532	468.801	468.801	468.801	11251.221
omic Cost	11207.491						307.022	328.862	354.984	363.548	378.964	378.964	378.964	9095.147
MINE COST														
ncial cost - Undiscounted	15198.967	97.887	195.774	170.593	70.342	127.702	439.925	496.440	477.775	616.414	573.482	681.412	468.801	11251.221
Discounted at 12%	3059.789	97.887	174.798	135.996	50.068	81.157	249.625	251.512	216.121	248.959	206.803	219.396		1127.466
omic cost - Undiscounted	12292.749	80.094	160.188	136.450	56.332	103.193	356.448	403.505	385.924	498.154	464.451	552.863	378.964	9095.147
Discounted at 12%	2476.930	80.094	143.025	108.777	40.096	65.581	202.258	204.428	174.572	201.196	167.486	178.007		911.409
RY CAPITAL COST														
cial cost	684.090			301.74		56.083	135.325	135.186	55.756					
mic Cost	602.311			269.157		50.6	117.84	117.701	47.013					
RY ANNUAL COST														
cial cost	5085.387						154.561	159.467	165.335	167.259	170.722	170.722	170.722	4097.322
mic Cost	4420.034						135.372	139.297	143.992	145.531	148.302	148.302	148.302	3559.238
WASHERY COST														
cial cost - Undiscounted	5687.698			269.157		50.600	272.401	277.168	212.348	167.259	170.722	170.722	170.722	4097.322
Discounted at 12%	1232.443			214.570		32.157	154.568	140.422	96.055	67.553	61.564	54.968		410.586
mic cost - Undiscounted	5022.345			269.157		50.600	253.212	256.998	191.005	145.531	148.302	148.302	148.302	3559.238
Discounted at 12%	1123.682			214.570		32.157	143.680	130.203	86.401	58.778	53.479	47.749		356.665
SYSTEM COST														
cial cost - Undiscounted	20886.664	97.887	195.774	439.750	70.342	178.302	712.326	773.608	690.123	783.673	744.204	852.134	639.523	15348.542
Discounted at 12%	4292.232	97.887	174.798	350.566	50.068	113.314	404.193	391.934	312.176	316.512	268.367	274.364		1538.052
ic cost - Undiscounted	17315.094	80.094	160.188	405.607	56.332	153.793	609.661	660.504	576.928	643.685	612.753	701.165	527.266	12654.385
Discounted at 12%	3600.612	80.094	143.025	323.347	40.096	97.738	345.938	334.632	260.973	259.974	220.965	225.756		1268.075
(from Middlings Sales)														
ial cost - Undiscounted	3202.097						39.6865	61.68662	88.0005	96.628	112.1575	112.1575	112.1575	2691.780
75/T) Discounted at 12%	478.901						22.51918	31.25236	39.80695	39.02642	40.44511	36.11171		269.73
ic cost - Undiscounted	2561.677						31.7492	49.3493	70.4004	77.3024	89.726	89.726	89.726	2153.42
40/T) Discounted at 12%	383.120						18.01534	25.00189	31.84556	31.22114	32.35609	28.88937		215.79
COAL COST														
ial cost - Undiscounted	17684.568	97.88685	195.7737	439.7504	70.34222	178.3022	672.6396	711.9208	602.1221	687.0449	632.0461	739.9760	527.3650	12656.762
Discounted at 12%	3813.332	97.88685	174.7979	350.5663	50.06820	113.3143	381.6738	360.6812	272.3695	277.4859	227.9221	238.2524		1268.313
ic cost - Undiscounted	14753.416	80.09400	160.1880	405.6065	56.33202	153.7929	577.9114	611.1543	506.5280	566.3827	523.0266	611.4388	437.5400	10500.9
Discounted at 12%	3217.492	80.09400	143.0250	323.3470	40.09601	97.73818	327.9224	309.6298	229.1275	228.7525	188.6086	196.8669		1052.283

Cost of Clean Coal from a 2.6 MT/a Opencast Mine+Kedla Washery (capacity utilisation of Mine & Washery at 85%)

Annexure 5.4/2

Mine: Rajrappa Grade: Medium Coking   All figure in millions of Rupees

Washery: Kedla

Costs at January 1989 Prices. WPI = 438.1   CPI:165   Indices for: Machinery-395.2; Vehicles-493.9

	TOTAL	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92 to 2014-15 Annual	1991-92 to 2014-15 Total
PRODUCTION														
Capacity	74.230						0.920	1.430	2.040	2.240	2.600	2.600	2.600	62.400
Discounted at 12%	11.102						0.522	0.724	0.923	0.905	0.938	0.837		6.253
Washery Production	34.146						0.423	0.658	0.938	1.030	1.196	1.196	1.196	28.704
Discounted at 12%	5.107						0.240	0.333	0.424	0.416	0.431	0.385		2.876
Middlings Production	21.527						0.2668	0.4147	0.5916	0.6496	0.754	0.754	0.754	18.096
Discounted at 12%	3.219						0.151	0.210	0.268	0.262	0.272	0.243		1.813
CAPITAL COST														
Financial cost	1336.728	97.887	195.774	170.593	70.342	127.702	61.045	90.262	38.948	166.882	104.681	212.611		
Economic Cost	1085.258	80.094	160.188	136.450	56.332	103.193	49.426	74.644	30.940	134.606	85.487	173.899		
ANNUAL COST														
Financial cost	14563.378						387.570	419.684	458.096	470.690	493.359	493.359	493.359	11840.620
Economic Cost	11768.447						313.974	339.668	370.400	380.476	398.613	398.613	398.613	9566.703
TOTAL MINE COST														
Financial cost - Undiscounted	15900.106	97.887	195.774	170.593	70.342	127.702	448.615	509.947	497.044	637.572	598.040	705.970	493.359	11840.620
Discounted at 12%	3164.651	97.887	174.798	135.996	50.068	81.157	254.556	258.355	224.837	257.505	215.659	227.303		1186.529
Economic cost - Undiscounted	12853.705	80.094	160.188	136.450	56.332	103.193	363.401	414.312	401.340	515.082	484.099	572.511	398.613	9566.703
Discounted at 12%	2560.826	80.094	143.025	108.777	40.096	65.581	206.203	209.903	181.546	208.033	174.571	184.333		958.663
WASHERY CAPITAL COST														
Financial cost	684.090			301.74		56.083	135.325	135.186	55.756					
Economic Cost	602.311			269.157		50.6	117.84	117.701	47.013					
WASHERY ANNUAL COST														
Financial cost	5211.396						156.123	161.894	168.798	171.061	175.135	175.135	175.135	4203.249
Economic Cost	4520.845						136.622	141.239	146.762	148.573	151.833	151.833	151.833	3643.983
TOTAL WASHERY COST														
Financial cost - Undiscounted	5813.707	0.000	0.000	269.157	0.000	50.600	273.963	279.595	215.811	171.061	175.135	175.135	175.135	4203.249
Discounted at 12%	1251.289	0.000	0.000	214.570	0.000	32.157	155.454	141.652	97.622	69.089	63.156	56.389		421.201
Economic cost - Undiscounted	5123.157	0.000	0.000	269.157	0.000	50.600	254.462	258.940	193.775	148.573	151.833	151.833	151.833	3643.983
Discounted at 12%	1138.760	0.000	0.000	214.570	0.000	32.157	144.389	131.187	87.654	60.006	54.752	48.886		365.158
TOTAL SYSTEM COST														
Financial cost - Undiscounted	21713.813	97.887	195.774	439.750	70.342	178.302	722.578	789.542	712.855	808.633	773.176	881.106	668.495	16043.869
Discounted at 12%	4415.940	97.887	174.798	350.566	50.068	113.314	410.010	400.007	322.459	326.593	278.815	283.692		1607.729
Economic cost - Undiscounted	17976.852	80.094	160.188	405.607	56.332	153.793	617.863	673.252	595.115	663.655	635.932	724.344	550.445	13210.687
Discounted at 12%	3699.585	80.094	143.025	323.347	40.096	97.738	350.592	341.091	269.200	268.039	229.323	233.219		1323.821
REVENUE (from Middlings Sales)														
Financial cost - Undiscounted	3767.172						46.69	72.5725	103.53	113.68	131.95	131.95	131.95	3166.800
(Rs.175/T) Discounted at 12%	563.412						26.49315	36.76748	46.83171	45.91344	47.58249	42.48436		317.340
Economic cost - Undiscounted	3013.738						37.352	58.058	82.824	90.944	105.56	105.56	105.56	2533.440
(Rs.140/T) Discounted at 12%	450.730						21.19452	29.41398	37.46537	36.73075	38.06599	33.98749		253.872
CLEAN COAL COST														
Financial cost - Undiscounted	17946.641	97.88685	195.7737	439.7504	70.34222	178.3022	675.8877	716.9695	609.3245	694.9533	641.2255	749.1555	536.5445	12877.068
Discounted at 12%	3852.527	97.88685	174.7979	350.5663	50.06820	113.3143	383.5166	363.2390	275.6274	280.6799	231.2323	241.2080	0	1290.3895
Economic cost - Undiscounted	14963.124	80.09400	160.1880	405.6065	56.33202	153.7929	580.5105	615.1942	512.2912	572.7110	530.3719	618.7841	444.8852	10677.246
Discounted at 12%	3248.855	80.09400	143.0250	323.3470	40.09601	97.73818	329.3972	311.6765	231.7345	231.3083	191.2574	199.2319	0	1069.9491

'Annexure 5.5.

Cost of coal handling at new coal unloading arrangement at Vishakapatnam port

	Cost of New Port & Handling Charges					
January 1989 Costs	WPI	438.100				
	CPI	165.000				
	Manfd. Prod.	411.000				

	TOTAL	YEAR 1	YEAR 2	YEAR 3	YEARS 4-33 Annual	YEARS 4-33 Total
Civil Works	243.146	81.010	121.456	40.681		
Mechanical Works	653.400	163.542	269.072	220.074		
Ex Works - Ind	352.942	88.323	154.321	110.298		
- FEC	94.359	23.618	31.415	39.326		
Freight&Insurance	7.549	1.889	2.513	3.146		
Customs Duty	56.049	14.029	18.661	23.360		
Excise Duty	49.059	12.277	21.451	15.331		
CST	15.882	3.975	6.944	4.963		
Instl.&Commg. - Ind	75.882	18.989	33.179	23.714		
- FEC	1.765	0.442	0.587	0.735		
Electrical Works	44.504	11.137	22.274	11.094		
Ex Works	34.772	8.701	17.403	8.668		
Excise Duty	4.260	1.066	2.132	1.062		
CST	1.648	0.412	0.825	0.411		
Instl.&Commg. - Ind	3.825	0.957	1.914	0.953		
Other Works	3.016			3.016		
Contingencies	28.234	7.671	12.384	8.179		
Engineering&Est	48.469	13.168	21.259	14.041		
Intst During Constn	64.450		21.500	42.950		
TOTAL - Financial	1085.306	276.527	467.945	340.834		
- Discounted	862.541	246.899	373.043	242.599		
-Economic	892.193	244.326	395.845	252.022		
- Discounted	713.098	218.149	315.565	179.384		
-Economic(25% pr on FEC)	915.783	250.2309	403.6988	261.8533		
- Discounted	731.629	223.421	321.826	186.382		
Coal Handled	105.000				3.500	105.000
- Discounted	20.069					20.069
Annual Cost - Financial	7910.921				263.697	7910.921
- Discounted	1512.041					1512.040
Economic	6844.937				228.165	6844.937
- Discounted	1300.296					1300.295
-Economic(25% pr on FEC)	6975.153				232.505	6975.153
- Discounted	1333.184					1333.184
TOTAL COST						
TOTAL - Financial	8996.227	276.527	467.945	340.834	263.697	7910.921
- Discounted	2374.582	246.899	373.043	242.599		1512.040
-Economic	7737.131	244.326	395.845	252.022	228.165	6844.937
- Discounted	2021.394	218.149	315.565	179.384		1300.295
-Economic(25% pr on FEC)	7890.936	250.231	403.699	261.853	232.505	6975.153
- Discounted	2064.813	223.421	321.826	186.382		1333.184

Economic Cost - 85%	3651.897			213.560	344.656	384.639	102.786	130.313	2606.257
Discounted	643.713			86.253	124.286	123.843	29.548		279.782
Total System Cost									
Financial Cost - 100%	13768.660	898.264	283.139	834.806	457.945	743.611	413.402	506.875	10137.493
	2295.365	218.458	128.078	337.164	165.140	239.423	118.843		1088.260
Economic Cost - 100%	12038.452	720.238	213.644	689.720	384.890	655.631	375.181	449.957	8999.147
	1974.175	175.162	96.642	278.566	138.795	211.096	107.856		966.058
Financial Cost - 85%	13045.345	898.264	283.139	834.806	457.945	727.940	393.058	472.510	9450.193
	2210.689	218.458	128.078	337.164	165.140	234.377	112.995		1014.478
Economic Cost - 85%	11459.816	720.238	213.644	689.720	384.890	643.095	358.906	422.466	8449.322
	1906.436	175.162	96.642	278.566	138.795	207.059	103.177		907.035
Revenue from Middlings									
Financial Cost - 100%	3471.605					75.211	97.643	164.938	3298.750
(@Rs.175/T) Discounted	406.407					24.216	28.070		354.121
Economic Cost - 100%	2777.284					60.169	78.114	131.950	2639.000
(@Rs.140/T) Discounted	325.126					19.373	22.456		283.297
Financial Cost - 85%	2950.864					63.930	82.997	140.197	2803.938
(@Rs.175/T) Discounted	345.446					20.584	23.860		301.003
Economic Cost - 85%	2360.691					51.144	66.397	112.158	2243.150
(@Rs.140/T) Discounted	276.357					16.467	19.088		240.802
Clean Coal Cost									
Financial Cost - 100%	10297.055	898.264	283.139	834.806	457.945	668.399	315.759	341.937	6838.743
Discounted	1888.958	218.458	128.078	337.164	165.140	215.207	90.773		734.139
Economic Cost - 100%	9261.168	720.238	213.644	689.720	384.890	595.462	297.067	318.007	6360.147
Discounted	1649.049	175.162	96.642	278.566	138.795	191.723	85.400		682.762
Financial Cost - 85%	10094.481	898.264	283.139	834.806	457.945	664.011	310.061	332.313	6646.255
Discounted	1865.244	218.458	128.078	337.164	165.140	213.794	89.135		713.475
Economic Cost - 85%	9099.125	720.238	213.644	689.720	384.890	591.951	292.509	310.309	6206.172
Discounted	1630.080	175.162	96.642	278.566	138.795	190.592	84.089		666.233